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SERDP

Strategic Environmental Research and Development Program

ANNUAL REPORT TO CONGRESS

Fiscal Year 2003

March 2004

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ANNUAL REPORT TO CONGRESS—
FISCAL YEAR 2003

FROM THE
STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM

March 2004

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EXECUTIVE SUMMARY

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's corporate environmental science and technology program. To fulfill its mission to address environmental problems through innovative research and share that information across federal and private organizations, SERDP executes the program in partnership with the Department of Energy and the Environmental Protection Agency. Further, SERDP fully leverages complementary programs within the Department of Defense and solicits interest from other public and private research organizations.

The organization and management of SERDP is described in Section I–Program Management. As directed by the SERDP Council, the Executive Director and Program Office Staff implement the Program with the support of various working groups and panels to meet high priority, DoD mission-related environmental needs. The activities, achievements, and recommendations of the SERDP Council, Scientific Advisory Board, and Executive Director are detailed in this section.

SERDP conducts basic research through advanced technology development in the following five Technology Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance (UXO). Section II–Significant Accomplishments describes significant accomplishments achieved during FY 2003 within each of the Thrust Areas. Highlights of these accomplishments include: (1) novel technologies for the remediation of energetics at munitions manufacturing facilities and on military training ranges (2) advanced sensors and data processing algorithms to improve detection and discrimination of buried UXO; (3) advances in the scientific understanding of the behavior of toxic metals from DoD vessels in marine environments and of the fate and transport in the environment of explosives compounds released from military munitions; (4) advanced modeling techniques to predict the impact of urban development and encroachment in the vicinity of military lands; and (5) elimination of the use of toxic compounds in the production of pyrotechnics and military munitions that are key to the success of our military forces.

In each fiscal year cycle, SERDP must manage ongoing research within the program, solicit and select new research projects, and plan future research initiatives and funding distribution for each Thrust Area. Section III–Program Description provides an overview of the SERDP Program, including the goals, environmental and operational research drivers, actual and planned funding levels, and the planned research initiatives for the Program. In FY 2003, SERDP was appropriated $54.6 million for the funding and management of 137 research projects. The FY 2004 appropriation of $50.6 million will be used for at least 121 projects, including both continuing and new start projects. Summaries of each project funded in FY 2003 and those planned for funding in FY 2004 are provided for the five Thrust Areas in Appendices A through E. Research topic areas for which proposals will be requested for projects to be funded in FY 2005 are provided in Appendix F.

This report provides a summary of SERDP's activities and its most significant accomplishments for FY 2003, its plans for FY 2004, and new research activities to be addressed in FY 2005. It responds directly to the requirements as stated in Title 10, U.S.C. section 2902, as modified. This report complies with FY 2001 amendment to the SERDP statute that repeals the requirement for an Annual Report from the SERDP Scientific Advisory Board, and includes the contents of that report in this Annual Report to Congress.

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I. PROGRAM MANAGEMENT

Background

Authorizing Legislation

In June of 1990, Senator Sam Nunn addressed the Senate to advise his colleagues about the seriousness of the environmental problems faced by this nation, and specifically by the Department of Defense (DoD) and the Department of Energy (DOE). Having recently been relieved of the strenuous efforts and financial burden of the Cold War, it became apparent to Senator Nunn and others that a significant capability existed both in the nation's Federal research infrastructure, as well as the defense industry, whose technical skills could be brought to bear on this Nation's environmental matters of concern. From this revelation, he recommended the creation of a Strategic Environmental Research Program, composed of several Agencies and Departments, that would seek to apply defense technologies for environmental benefits.

Later that year, Public Law 101-510 (Title 10, U.S.C., §§2901-2904) established the Strategic Environmental Research and Development Program (SERDP) funded by DoD and planned and executed in partnership with DOE and the Environmental Protection Agency (EPA). The immediate success of the Program led to SERDP becoming the DoD's corporate environmental Science and Technology (S&T) program. SERDP fully leverages complementary programs found within the Army, Navy, and Air Force, and those of the DOE and the EPA. Over the past decade, measures have been implemented to take full advantage of the intrinsic capabilities of the participating organizations. This feature makes SERDP unique, as it can tap the vast technical resources of the Federal research infrastructure to meet the needs of our most pressing environmental matters of concern. During the past seven years, SERDP has successfully engaged in directly funding the private sector and academia in a step that further widens the spectrum of technological capability and innovation.

This report provides a summary of SERDP's activities and most significant accomplishments during fiscal year 2003, its plans for fiscal year 2004, and new research initiatives to be addressed in fiscal year 2005. It responds directly to the reporting requirements as stated in Title 10, U.S.C. §2902. Subsection 2902(d)(3) was amended in 2000 to include subsection (D) which requires that the SERDP Annual Report contains a summary of the actions and recommendations of the SERDP Scientific Advisory Board (SAB) during the preceding year.

Mission

The purposes or mission of SERDP can be found in the statute and are paraphrased below. The clear intent of Congress was to not only address environmental problems through research efforts, but also to share information across and within Federal and private lines in order to more rapidly and effectively deal with these serious problems. Specifically, the four purposes of SERDP are to:

SERDP addresses DoD and congruent DOE environmental matters of concern through cooperative research.

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the Departments to meet their environmental obligations;
- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization,

hazardous waste substitution, and other environmental concerns and to share such research, technologies, and other information with such governmental and private organizations;

- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research; and

- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, and hazardous material substitution and provide for the use of such technologies in the conduct of such activities.

This mission, crafted over 13 years ago, remains highly relevant, and while significant successes have been achieved, a number of difficult technical challenges remain.

Requirements

SERDP is a “requirements-driven” program that directly responds to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense (Installations and Environment) [DUSD(I&E)]. It is critical that the limited funds available for environmental technology research and development (R&D) be focused on the highest priority requirements of the Services. Each Service develops prioritized user requirements through internal processes that include members of the technology user community. These requirements are collected, cross-referenced, and correlated at the DoD level by the DUSD(I&E).

The DoD’s environmental issues fall into two major categories. The first is the sustainability of the Department’s Training and Testing Ranges. Many of the ranges are under restrictions due to environmental issues and in a few extreme cases the range in unable to function at all. Access to adequate training ranges in perpetuity is essential military readiness. To assure this access, the environmental issues associated with the ranges must be addressed. The second major driver is the reduction of current and future liabilities. Current liabilities are associated with the remediation of contamination frm past practices. These are relatively well known and have been estimated to total $14 billion. However, that estimate does not include the liability from unexploded ordnance (UXO) or emerging contaminants such as perchlorate (ClO_4^-). Future liabilities are in the form of the toxic and hazardous materials and emissions from today’s weapons and platforms. The aggressive development of new, benign materials and industrial processes as well as control technology, the use and release of these materials to the environment can be reduced or eliminated. Technology has proven to be capable of significantly reducing the cost of addresses all of these liabilities.

All of these categories have a direct impact on the Department’s ability to perform its primary mission of maintaining military readiness for national defense. For the ease of managing the program, SERDP places all research efforts into one of five thrust areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance.

In the course of addressing DoD’s highest priority environmental needs, SERDP also has sought opportunities to help solve other significant national and international environmental problems through the application of DoD’s technical capabilities, analytical systems, and information.

The SERDP Management Structure

SERDP is a multi-agency managed program funded by the DoD. Pursuant to Title 10, U.S.C., SERDP receives general oversight and policy guidance from the SERDP Council which is composed of members

from the DoD, DOE, and EPA. Also included in this authorizing language is a requirement for an Executive Director to lead the day-to-day Program activities, and a SAB that is charged with providing advice and recommendations to the SERDP Council on projects/proposals reviewed. Further, the SAB may advise the Council regarding other programmatic, funding, or technically related issues with respect to the Program. Other activities shown in Figure I-1 represent those that were established by the Council and Executive Director to support Program needs.

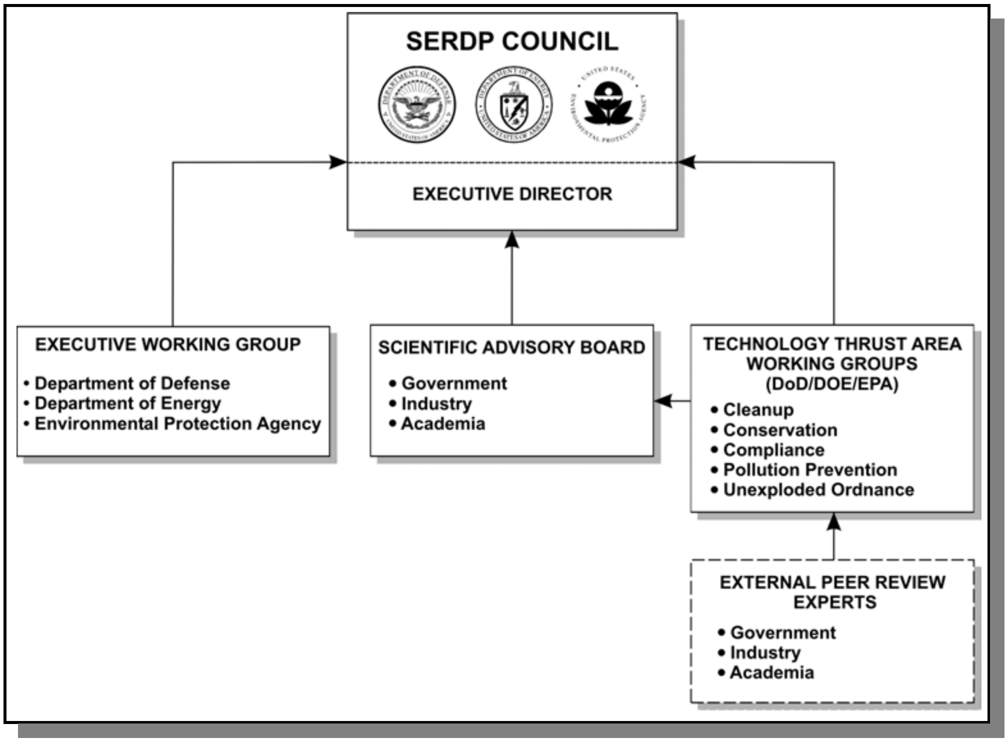

Figure I-1. SERDP Organization.

SERDP Council

Established by law, SERDP's multi-agency Council ensures integrated, non-duplicative research.

Title 10, U.S.C. §2902 established the SERDP Council to oversee management of SERDP. Specifically, this Council prescribes policies and procedures to implement the Program and, uniquely, is the sole funding approval authority. As such, the Council may enter into contracts, grants, and other agreements in accordance with other applicable law to carry out the purposes of SERDP. Congress intended the Council to be a multi-agency membership body to promote maximum exchange of information and to minimize duplication of environmentally related research, development, and demonstration activities through close coordination with the military departments and Defense agencies; the DOE; the EPA, the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; other departments and agencies of the Federal, State, and local governments; and other organizations engaged in environmentally related research.

DoD and DOE Council representatives alternate as Chair.

Consistent with the SERDP statute and with facilitating multi-agency cooperation, the Secretary of Defense has designated the Deputy Under Secretary of Defense for Science and Technology (DUSD/S&T) as chairperson for each odd-numbered fiscal year, and the Secretary of Energy has designated the Director of the Office of

Science to serve as chair for each even-numbered year. Other members are assigned per guidance provided in the SERDP statute. The following are the Council members who served during a portion of, or for the entire, FY 2003.

Council Members - FY 2003

Dr. Everet H. Beckner
National Nuclear Security Administration
U.S. Department of Energy

Lt. Col. Jeff Cornell
Office of Deputy Assistant Secretary of the Air Force
Environment, Safety and Occupational Health
U.S. Air Force

Mr. Ray DuBois
Installations & Environment
Department of Defense

Captain Jim Evans
Research and Development
U.S. Coast Guard

Dr. Paul Gilman
Office of Research and Development (ORD)
U.S. Environmental Protection Agency

Dr. Charles J. Holland
Deputy Undersecretary of Defense, Science and Technology

Dr. Stephen Lubard
Office of Naval Research (ONR)
U.S. Navy

Dr. Ray Orbach
Office of Science
U.S. Department of Energy

Mr. James Owendoff
Office of Science and Technology
Office of Environmental Management
U.S. Department of Energy

General Peter Pace
Joint Chiefs of Staff

Dr. John Parmentola
Research and Laboratory Management
U.S. Army

Mr. Bradley Smith *(non-voting member)*
Executive Director
Strategic Environmental Research and Development Program

Executive Working Group

The Executive Working Group (EWG) is an extension of the Council and serves as a working-level representation of the Council. This body, while not established by law, facilitates SERDP policy preparation, investment strategy considerations, and annual program plan development.

SERDP Scientific Advisory Board

SAB members focus on technical quality.

Established in accordance with the SERDP statute, the SERDP SAB assures that the Program maintains clear focus on technical quality. The SAB has the authority to make recommendations to the Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP. The SAB is composed of no more than 14 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the EPA. During FY 2003, three members completed their tenure on the Board late in FY 2003 leaving the Board with a total of ten members. SERDP has successfully identified new candidates for membership in 2004.

To ensure that SERDP objectives are congruent with the Administration's goals, two members of the SAB are mandated in the statute - the Science Advisor to the President, or his/her designee, and the Administrator of the National Oceanic and Atmospheric Administration, or his/her designee. Similarly, to ensure that

regional and global environmental issues are appropriately addressed in SERDP, at least one member should represent the interests of State governments and one member should represent environmental public interest groups. The list below reflects SAB membership in FY 2003.

Scientific Advisory Board Members - FY 2003

Dr. Paul Anastas
White House Office of Science and Technology

Dr. Mary Barber
The Ecological Society of America

Dr. Ann Bartuska
The Nature Conservancy

Dr. Jeffrey Daniels
The Ohio Sate University

Dr. Ronald Heck
RMH Consulting

Dr. Carol Henry
American Chemistry Council

Dr. Michael Kavanaugh
Malcolm Pirnie, Inc.

Dr. William Neff
National Oceanic and Atmospheric Administration

Dr. Jeffrey J. Siirola
Eastman Chemical Company

Dr. Jean'ne M. Shreeve (Vice Chair)
University of Idaho

Dr. C. Herb Ward (Chair)
Rice University

Mr. Randolph Wood
Texas Natural Resources Conservation Commission

Dr. Lily Young
Rutgers University

The statute directs the SAB to review all projects with a value in excess of $1,000,000. Several years ago, the SERDP Council modified this direction by requesting that each new start effort and every continuing project exceeding $900,000 be reviewed by the SAB. During FY 2003, each project meeting this criteria was reviewed to ensure technical quality and fiscal responsibility. Furthermore, the SAB confirmed that multiple projects responding to the same or a similar requirement were complementary in approach and well coordinated.

Executive Director and Program Office Staff

Title 10, U.S.C. authorizes an Executive Director to direct and focus the day-to-day efforts of SERDP, and Mr. Bradley P. Smith retained the position of Executive Director. The Executive Director is a non-voting member of the SERDP Council and a voting member of the EWG. Dr. Jeffrey Marqusee, the Environmental Security Technology Certification Program (ESTCP) Director, also served as the SERDP Technical Director. Collocation of SERDP and ESTCP has served to broaden the staff's technical skills and facilitate technology transition from one program to another. The balance of the Federal staff consisted of four technical Program Managers and a Financial Officer who have been detailed from the military Services' R&D infrastructure. These individuals include:

- Dr. Anne Andrews - Program Manager for UXO technologies
- Dr. Andrea Leeson - Program Manager for Cleanup technologies
- Mr. Charles Pellerin - Program Manager for Pollution Prevention technologies
- Dr. Robert Holst - Program Manager for Compliance and Conservation technologies
- Ms. Brenda Batch - Financial Officer
- Ms. Margaret Banks - Financial Officer

Technology Thrust Area Working Groups

As evidenced by the small size of Program Office staff, the breadth of technical knowledge demanded by SERDP far exceeds the limited staff in the SERDP Program Office. Consequently, SERDP must rely on the technical skills offered by the participating Services and Agencies to assist in the technical aspects of program development, program monitoring, and technology transfer. For each of the Technology Thrust Areas, a Technology Thrust Area Working Group (TTAWG) was established to help solicit and review technical proposals, formulate and recommend the annual program plan, conduct technical reviews of the ongoing projects, and facilitate technology transfer according to the needs of their users in the field. TTAWGs offer several advantages over conventional R&D management schemes. First, their members are selected by the Services and Agencies as represented on the Council. Second, they bring not only a wealth of understanding of the needs of their organization, but also knowledge of similar completed or ongoing efforts. This knowledge helps SERDP to avoid duplication of effort and promote joint and cooperative funding of projects. TTAWG members, for the most part, are provided from their organizations as a collateral assignment, however, without their assistance, SERDP would have difficulty achieving the same level of success.

Peer Review Experts

Assisting the TTAWGs and the Program Office in their quest to select quality research proposals are the Peer Review Experts. Following the model established by the National Science Foundation, SERDP proposals must undergo an independent Peer Review prior to receipt of initial funding. The results, scores, and evaluation comments of this review are passed directly to the TTAWGs who use this information to develop their recommended list of new start projects. Further, these same results are passed to the SAB for consideration during their proposal review and deliberations.

SERDP supports an electronic peer evaluation process via the Internet.

Peer Reviewers come from all walks of disciplinary life - from industry, academia, and government as well. Each reviewer is certified to be without conflict of interest, an expert in their field and profession, and credible on record. Peer Reviewers are identified and tasked under a support contract, and in FY 2003, 117 Peer Review Experts were used to evaluate 203 proposals.

SERDP Strategy

Program Goals

The SERDP Council ensures that the partnership focuses on the mission needs of the DoD and empowers the EWG with developing goals and an investment strategy that will assist SERDP to successfully satisfy these mission needs. In 1993, the EWG assembled to develop the broad SERDP Strategic Guidance that served as a framework within which to develop the annual SERDP program plan. This Strategic Guidance continues to provide the overarching guidelines to Program Managers and participants in the Program. Included in this document are the SERDP goals which are to:

- Resolve environmental concerns in ways that enhance military operations, improve military systems effectiveness, and help ensure the safety of personnel; and

- Support technology and process development that reduce operational and life cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

SERDP achieves its goals by promoting cooperative environmental technology development and a strong effort in information dissemination. Specifically, SERDP succeeds by:

- Identifying and supporting programs of basic and applied research and development to:
  - Accelerate cost-effective cleanup of contaminated defense sites.
  - Facilitate full compliance with environmental laws and regulations at reduced cost.
  - Enhance training, testing, and operational readiness through prudent land management and conservation measures.
  - Reduce or eliminate defense industrial and operational waste streams through aggressive pollution prevention programs that strongly encourage use of non-hazardous, non-toxic, non-polluting, and other environmentally sound materials, substances, and processes.
- Promoting the effective exchange of information regarding environmentally related research and development activities.
- Ensuring that SERDP R&D activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities.

SERDP promotes cooperative environmental technology development and information transfer.

- Providing appropriate access to data under the control of, or otherwise available to the DoD and DOE that is relevant to environmental matters.
- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society that might be able to use them to advance national environmental objectives.
- Emphasizing multi-service, inter-departmental research and development projects and using the unique capabilities of the partnering Federal agencies, private industry, and academia to solve the Departments' environmental problems.

Investment Strategy

In 2003, the SERDP staff, in conjunction with the SAB, developed a more specific investment strategy. The EWG and SERDP Council approved the goals and objectives of this investment strategy. The core of the investment strategy is as follows:

SERDP is the DoD's corporate environmental science and technology program. The broad purpose is:

> *To address environmental matters of concern to the DoD through support for basic and applied research and development of technologies that can enhance the capabilities of the departments to meet their environmental obligations.*

There are two major ways in which environmental issues impact the military. The first, and most dramatic, is the curtailment or prohibition of military training and testing operations. The second major impact is the costs associated with both compliance with environmental regulation and environmental restoration. These costs represent a significant future liability for the Department. Both of these broad issues have significant impacts on the ability of the Department to fulfill its mission. As such, they form the basis of the following overarching goals of SERDP.

- Develop and transition environmental technologies that permit DoD training and testing ranges to continue to provide venues for realistic and comprehensive training into the future in a sustainable fashion.

- Develop and transition technologies that reduce the Department's current and future liability by reducing life-cycle costs for all aspects of military operations impacted by compliance with environmental regulation.

Training and Testing

Military operations cover a wide range of activities from firing weapons, to flying aircraft to using shipboard sonar systems. One of the painful lessons that the Services have learned over the years is that "you fight as you train." It is vitally important that the men and women of the Services have the ability to exercise themselves, their platforms and their weapon systems through the full range of capability in a realistic environment. Similarly, the ability to test new weapons technology is essential to the development and eventual deployment of superior capability. The ability to train and test has been restricted in a variety of ways for a variety of reasons. The environmental threats to training and testing must be addressed to ensure access to training into the foreseeable future.

Current and Future Liability

Current and future environmental liability for the Department lies in two broad categories. The first is the remediation of past practices - environmental cleanup in the vernacular. While these current liabilities are relatively well known, discoveries of new types of contamination such as explosives and rocket fuel constituents continue to surface. The second broad category of liabilities lies in the costs to control and treat wastes and toxic substances. These future liabilities frequently are associated with the industrial processes required to build and maintain military hardware. The preferred means to address these issues is to view systems in a total life-cycle management framework and eliminate hazardous and toxic materials when possible. The liabilities associated with both of these categories have been significantly reduced through the development and application of new, advanced, environmental technologies.

Key Metrics for SERDP Success

The following four key metrics are used to maintain Program quality and enhance the success of the Program:

1. Address the highest-priority, defense mission-relevant environmental requirements with emphasis on multi-service issues.

The Executive Director and his staff worked hand-in-hand with Office of the Deputy Under Secretary of Defense (Installations and Environment) [ODUSD(I&E)] to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Through the use of focused Statements of Need (SONs), the Executive Director solicited cooperatively funded and executed projects to address high-priority multi-service needs. The TTAWGs facilitated this process by communicating effectively and applying their knowledge of the needs of the services and the capabilities of the Federal R&D infrastructure.

SERDP often holds workshops to explore the state-of-science, technology gaps, and opportunities for research in need areas where it may be difficult to interpret this need. From these workshops, several key SONs can be identified. In FY 2003, SERDP staff initiated planning for two workshops to be led in FY 2004, one on contaminated sediments in aquatic environments and one on the state of the science and engineering for electromagnetic induction (EMI) technology used for detection and discrimination of UXO.

2. Pursue/achieve universal, world-class technical excellence.

World-class research is considered the cornerstone of SERDP projects. Continuing the successful solicitations of the past few years, SERDP solicited proposals from all sources including the non-Federal sector. SERDP continued to use external Peer Review Experts in addition to the comprehensive multi-agency review procedures to ensure that technically sound proposals performed by world-class researchers are selected for funding. Technical experts representing universities, industry, and government participate in the Peer Review process. Additionally, the SAB, TTAWGs, and the Program Office staff all emphasize the need for each research team to demonstrate superior technical merit and perform according to world-class research standards.

3. Emphasize and promote technology transfer.

Transfer of technology, from research to the DoD environmental user community, is one of the key objectives of SERDP. This objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority, DoD mission-related, environmental needs. With FY 2003 marking its eleventh year of technology development, SERDP is aggressively pursuing technology transfer mechanisms. The co-location of ESTCP with SERDP has already helped to facilitate project transitions, both between Programs and into other Agencies' certification programs as well. Many of the SERDP projects initiated in the earlier years have been, or are being completed and are now ready for field demonstration, implementation, or transition to the next step of development.

Significant focus on technology transfer has been placed on the Principal Investigators (PI) of all SERDP projects at both briefings to the SAB as well as at the In-Progress Reviews (IPR). At these IPRs, PIs are required to demonstrate their interaction with the user community or those who will sponsor further development. Members of the multi-agency TTAWGs, Joint Engineers Management Panel (JEMP) members, and key representatives from ODUSD(I&E) attended the IPRs in FY 2003 and provided various potential technology transfer opportunities to the PIs.

4. Ensure sound fiscal management.

Timely and complete financial reporting is one of the principal keys to SERDP's success. The SERDP Executive Director has continued to ensure that the Program complies with the DoD fiscal guidance. Effective controls include periodic fiscal review of projects, implementing aggressive corrective actions to promote effective use of limited R&D resources, and implementation of various information management/monitoring tools which fully utilize state-of-the-art Internet capabilities.

Research Framework and Technical Strategy

SERDP has the flexibility to fund basic and applied research, or advanced technology development projects as needed.

Within the Services' Environmental Quality Programs, Program Elements exist to provide funding specifically focused on either basic research, applied research, or advanced technology development. The authors of SERDP's statute understood the need to easily and judiciously allocate funds against the highest priorities and most intractable problems faced by DoD. Accordingly, SERDP has the flexibility to perform under all of these research categories. Figure I-2 illustrates SERDP's role in the DoD environmental technology development process.

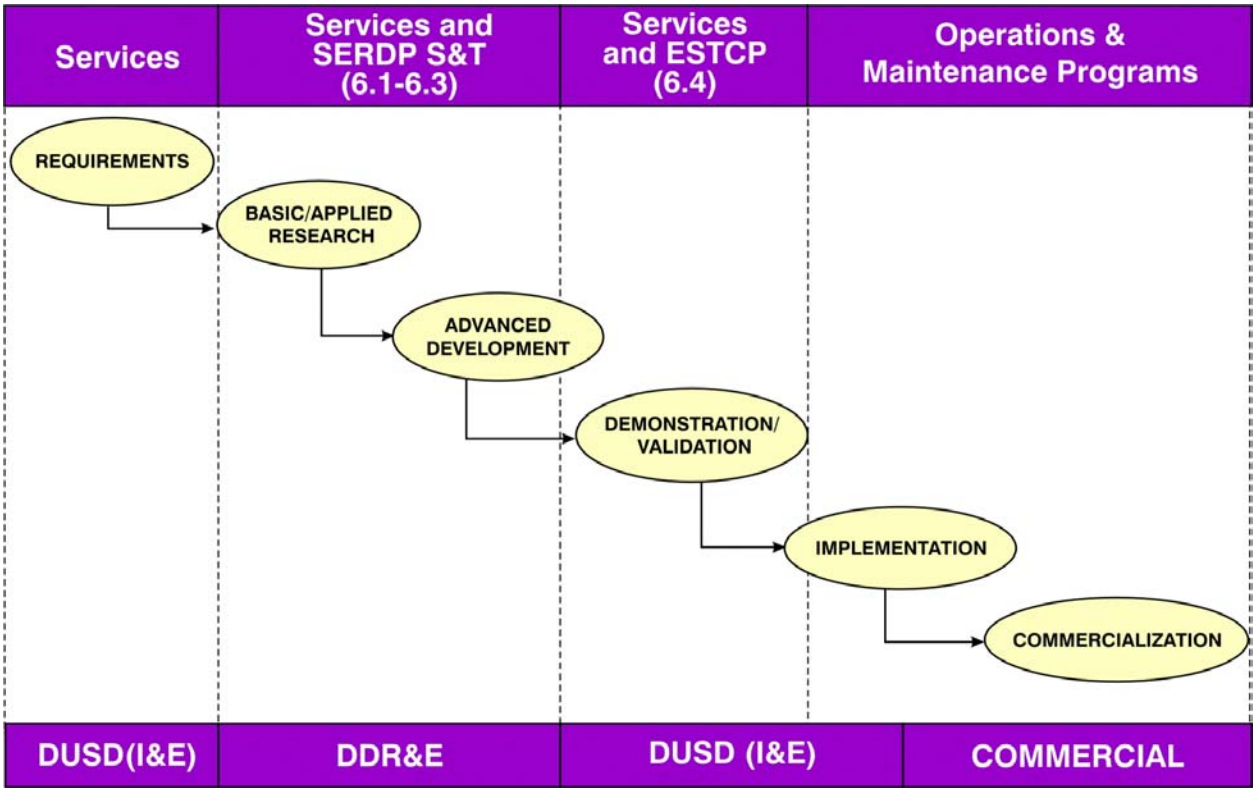

Figure I-2. Environmental Technology Development Process.

Figure I-3 represents the research taxonomy that defines the SERDP Program. The primary areas of emphasis were developed in response to user community needs for science and technology required to accomplish the military mission in an environmentally compliant manner. This taxonomy follows the four pillar structure that is consistent with the focus of the ODUSD(I&E), that corresponds to those identified in the National Environmental Technology Strategy. The research taxonomy reflects the current areas of emphasis under each of the five pillars.

CLEANUP	COMPLIANCE	CONSERVATION	POLLUTION PREVENTION	UNEXPLODED ORDNANCE
Site Characterization and Monitoring	Air Emissions Monitoring and Control	Ecosystems Restoration and Mitigation	Air Emissions	Wide Area Assessment
Remediation	Marine Environmental Issues	Threatened and Endangered Species	Elimination of Chromium/Cadmium	Production Ground Surveys
Risk Assessment Technologies	Energetic Materials in the Environment	Ecosystem Processes	Green Energetics	Cued Identification
	Solid Waste and Wastewater Treatment	Cultural Resource Management	Next Generation Fire Suppression	Standards and Protocols
	Noise	Ecological Forecasting	Hazardous Materials and Solid Waste Reduction	Recovery and Destruction
	Water Quality			Decision Tools

Figure I-3. SERDP Research Taxonomy.

Technical Strategy

For FY 2003, the SERDP Council directed the continuing pursuit of seven avenues in planning and executing defense mission-relevant environmental research and development:

- ✔ Identify and fund major-impact, multi-agency environmental R&D programs to solve high- priority, mission readiness related concerns of DoD;
- ✔ Identify opportunities to accelerate existing DoD environmental quality R&D programs and fund those that address the highest priority concerns of the Department;
- ✔ Advance and use applicable state-of-the-art modeling and simulation capabilities to accomplish SERDP goals;
- ✔ Use the technical and research capabilities of the SERDP partners, including their unique data collection and analysis capabilities, as appropriate;
- ✔ Plan for a transition of successfully proven technologies to demonstration and validation or to commercialization and implementation; and
- ✔ Encourage high-risk, high-payoff novel approaches to resolve environmental problems through the use of low-cost, short-term, exploratory R&D efforts.

Search for Innovation

With respect to the last strategic element, SERDP continues to seek innovative ideas with commensurate technical risk. The SERDP Exploratory Development Program, or SERDP Exploratory Development (SEED), that was initiated in FY 1999, has succeeded in soliciting novel ideas that were demonstrated under a low-cost ($100,000 or less), short-term (one year), proof-of-concept study. SEED projects and the larger, longer-term "Core" efforts both respond to the highest priority needs as defined in published SONs. These SONs are released annually with a Federal Call for Proposals and a non-Federal Broad Agency Announcement (BAA). In search of world-class research, SERDP promotes direct participation from the private sector, including small and large businesses and academic institutions. In FY 2003, seven of these SEED efforts (three in Cleanup, one in Compliance, one in Conservation and two in Pollution Prevention) were successful in their study phase and are expected to propose follow-on work for FY 2004. The accomplishments of these efforts are described in Section III entitled, "Program Description" and Appendices C, D, and E.

Investment Plan

Each year the SERDP Council annually determines the distribution of funding to the Thrust Areas. The Council seeks the advice and recommendations of the SERDP SAB and the EWG to best position SERDP to respond to both pressing needs as well as environmental problems that loom in the future. For FY 2003, the Council had approved shifting the allocation of resources among the pillars in recognition of the growing impact that environmental issues are having on training and testing ranges as well as the enormity of the future liability for the remediation of lands contaminated with UXO. These funds were directed by the issues of UXO remediation and environmental issues impacting the sustainability of military training and testing ranges.

The FY 2004 President's Budget Request for SERDP was $47.1 million, a decrease of $7.5 million from the FY 2003 appropriation. Congress increased the amount appropriated for SERDP in FY 2004 to $50.6

million. The investment allocation among the five thrust areas in FY 2004 has remained relatively unchanged, with the largest percentages going to Pollution Prevention, followed by Cleanup and UXO, Conservation and Compliance. Within these thrust areas, SERDP will focus its allocation of resources to address high-priority requirements that cut across thrust areas, in accordance with SERDP's investment strategy.

Actions of the SERDP Scientific Advisory Board

In accordance with Section 2904, Title 10, U.S.C., the SAB is required to meet a minimum of four times during the Fiscal Year. In FY 2003, the SAB met four times, with each meeting held in Arlington, VA. Consistent with the statute, the Board made recommendations to the SERDP Council through the Executive Director regarding the projects reviewed. They also assisted and advised the Council in identifying environmental opportunities and provided advice on other environmental issues within the scope of SERDP.

Figure I-4 provides a list of dates and locations of all SAB meetings held during FY 2003. In accordance with the Federal Advisory Committee Act, all meetings were open to the public and detailed records of events are maintained. Further, all records, reports, working papers, and agendas were made available to the public for review. In FY 2003, no requests were made to review this information.

SAB Meeting No.	Dates	Location	Projects Briefed		
			New	Ongoing	Total
1	October 15, 2002	Arlington, VA	1	5	6
2	March 12-13, 2003	Arlington, VA	1	7	8
3	June 11, 2003	Arlington, VA	2	4	6
4	September 10-12, 2003	Arlington, VA	23	--	23

Figure I-4. Summary of FY 2003 SAB Meetings.

During FY 2003, the SAB continued to be committed to enhancing three processes within SERDP: research initiation, quality control, and technology transfer.

Commitment to Enhancing the Research Initiation Process

Consistent with the SAB's desire to define and fulfill its role within SERDP's statutory requirements, in a manner that most effectively utilizes the collective expertise and experience of the Board, the SAB reaffirmed its commitment to ensure that SERDP complies with the statute by soliciting and funding projects that are sharply focused on the environmental needs of the DoD and those congruent needs of the DOE. The Board reviewed and contributed to the process of preparing and issuing SONs. In the course of review, the SAB was instrumental in identifying opportunities to enhance the expected research product. Additionally, their final quality control review ensured that the SONs clearly articulated the objective of each and every need. This process was instrumental to fostering properly focused research proposals and minimizing irrelevant submissions in response to the broad solicitation.

The Board continued its proactive strategic role in identifying and defining environmental research gaps and associated technology development opportunities. The Board continued to support strongly the concept of focused technical workshops to provide an assessment of the state of the science and identify and prioritize

research needs specific in areas of interest to SERDP. As a result of workshops held in the past, numerous SONs were generated that resulted in many proposals.

During their review and evaluation of proposals, the SAB conscientiously scrutinized each effort to understand and enhance the research partnerships that were proposed. Considered to be a major strength of the Program, cooperative research efforts have demonstrated a higher quality of effort by ensuring that each facet of the project is afforded a second look and chance to ensure that it is conducted with the highest standards. Where appropriate, the SAB suggested improvements or additions to the research team - from inclusion of a Co-PI having specific disciplinarian credentials that would enhance the research effort, to offering suggestions of organizations that might shed additional light and enhance the standards and procedures proposed in the effort. The SAB also strongly encouraged inclusion of graduate students in research teams to promote training and foster development of technical expertise in cutting edge technologies.

Commitment to Ensuring Quality Research

The Board continued its key focus on assisting SERDP to ensure that SERDP-supported projects meet the highest standard of technical and scientific quality. The SAB addressed this issue from three avenues.

- First, the members strongly endorsed the established proposal review process. The SAB firmly supports SERDP's procedure to have each and every proposal reviewed by at least three Peer Reviewers that are experts in the discipline most closely related to the proposal's technical approach. All Peer Review comments are forwarded to the SAB prior to their meetings and are used extensively by the members during proposal discussions with the Principal Investigator. These review comments complement the Board members' already diverse and deep technical expertise.

- Second, the members encouraged close coordination between projects that address related problems. In this sense, the Board evaluated projects on more than just the basis of their individual scientific merit and DoD relevance, putting increasing emphasis on coordination and leveraging between projects to ensure that related efforts indeed complement each other. As demonstration of this emphasis, the Board voiced its support for the use of a Technical Advisory Committee for "umbrella"-type projects, i.e., those that are a conglomeration of subprojects and centrally managed by a laboratory or agency representative. Projects in this category include Next Generation Fire Suppression Technology Program, the SERDP Ecosystem Management Program, and the Green Medium Caliber Ammunition Program.

Technical Quality Control is a recurring theme for the Scientific Advisory Board.

- Third, the Board fully supported the mid-year In-Progress Review of each project by the TTAWGs. While the SAB's primary function is to assess the technical aspects of SERDP projects, the Board has insufficient time to conduct a thorough technical evaluation of each ongoing project. The TTAWG is the appropriate group to perform this assessment. However, often times SAB members did attend and participate in some of the mid-year review meetings.

Commitment to Technology Transfer

The SAB continued to emphasize technology transfer potential as an important criterion for evaluating proposals. Technology transfer is one of the SERDP Keys to Success, and the Board members continued their keen interest in the role of the military Services and eventual users of the technologies being developed.

Complete technical reporting, including publications in the peer-reviewed literature as well as SERDP-required interim and final technical reports, was a metric used to determine project technical achievement and management acumen. The SAB fully supported SERDP's requirement for annual/interim technical reports and a final technical report upon completion of the project. These reports constitute technical progress to date, whether successful or not, on each project's technical approach. According to the Board, the value of "negative results" cannot be overstated, and SERDP projects should clearly state their progress and publish these results to facilitate further research.

The SAB continued its participation in the planning and execution of the annual *Partners in Environmental Technology Technical Symposium and Workshop* sponsored by SERDP. During strategy discussions at SAB meetings, the members offered comments on the overall theme of the Symposium and suggestions for technical session topics and plenary and session speakers. SAB members continued the tradition of active involvement in the planning of technical breakout sessions. The Board continued to demonstrate its commitment to involvement at the latest Symposium held in December 2003, with Dr. Herb Ward, Chair of the SAB, presenting the SERDP FY 2003 Project of the Year Awards. The active involvement of the SAB has been a significant contributing factor to the overall success of each Symposium.

Areas of Opportunity

In the past the SAB has suggested areas of opportunity for SERDP investment. Often, these areas prove to become the focus of a national or world-wide research effort. An example of research that commenced at the suggestion of the Board is the remediation of groundwater contaminated with ClO_4^-. Due to their proactive thinking, SERDP was able to get a head start on understanding this phenomenon and initiating research to resolve associated issues.

Consistent with past practice, the Executive Director solicited the advice of the membership regarding his proposed allocation of funds among the five Thrust Areas for FY 2003. The Board was fully supportive of the proposed profile and general trends of investment within each of the five Thrust Areas.

Project and Program Recommendations

During FY 2003, the SAB reviewed 42 proposals/projects, 27 of which were new start efforts and 15 of which were continuing projects. Of these 42 efforts, 13 requested FY 2003 funds totaling $11,051,000. A total of 24 projects requested $9,822,000 in FY 2004 funds. The Board recommended against funding two FY 2004 proposals. A summary of all projects reviewed and the results of their deliberations may be found in Figure I-5.

At the September 2003 SERDP Council meeting, Dr. C. Herbert Ward, Chair of the SAB advised the Council of how the SAB ensures that quality research is focused on high-priority DoD needs and that technology transfer is fostered to the users in the field. Dr. Ward was supportive of the Program stating that during his tenure, SERDP has become increasingly more rigorous and funding higher quality research overall. He opined that SERDP research on state-of-the-art technologies is well published and is recognized worldwide. He noted that budget cuts in FY04 have made significant negative impacts; adding that additional funding could support several value-added projects.

Project Number	Recommendation				FY03 Meeting Date				New Starts	Continuing Projects
	Fund		Not Fund		1	2	3	4		
	FY03	FY04	FY03	FY04	Oct-02	Mar-03	Jun-03	Sep-03		
CP-819 (1)			$ 2,000				Jun-03		●	
CP-1155		$ 1,433					Jun-03			●
CP-1245 (2)						Mar-03				●
CP-1254 (2)						Mar-03				●
CP-1255 (2)						Mar-03				●
CP-1256 (2)						Mar-03				●
CP-1397		$ 345						Sep-03	●	
CP-1398		$ 226						Sep-03	●	
CP-1401		$ 559						Sep-03	●	
CP-1402		$ 711						Sep-03	●	
CS-1114	$ 2,432				Oct-02	Mar-03				●
CS-1189 (2)							Jun-03			●
CS-1257	$ 400				Oct-02					●
CS-1333	$ 394				Oct-02				●	
CS-1389	$ 326							Sep-03	●	
CS-1303	$ 127							Sep-03	●	
CU-1204	$ 486				Oct-02					●
CU-1235 (1)	$ 2,000					Mar-03			●	
CU-1365	$ 26						Jun-03		●	
CU-1368		$ 151						Sep-03	●	
CU-1369		$ 235						Sep-03	●	
CU-1370				$ 326				Sep-03	●	
CU-1371		$ 488						Sep-03	●	
CU-1374				$ 237				Sep-03	●	
CU-1376		$ 295						Sep-03	●	
CU-1377		$ 180						Sep-03	●	
CU-1378		$ 318						Sep-03	●	
PP-1059		$ 1,000					Jun-03			●
PP-1133 (2)						Mar-03				●
PP-1179	$ 995				Oct-03					●
PP-1270	$ 252				Oct-03					●
PP-1403		$ 270						Sep-03	●	
PP-1404		$ 535						Sep-03	●	
PP-1405		$ 375						Sep-03	●	
PP-1406		$ 470						Sep-03	●	
PP-1408		$ 291						Sep-03	●	
PP-1409		$ 310						Sep-03	●	
UX-1225	$ 544					Mar-03				●
UX-1327	$ 1,069						Jun-03			●
UX-1380		$ 478						Sep-03	●	
UX-1381		$ 401						Sep-03	●	
UX-1382		$ 188						Sep-03	●	
TOTALS	**$ 9,051**	**$ 9,259**	**$ 2,000**	**$ 563**					**27**	**15**

(1) Congressional Earmark.
(2) Project update to Board; no vote on funding required.

Figure I-5. Summary of Proposals Reviewed by SAB in FY 2003 by Thrust Area (Funding in Thousands).

Other Management Actions

Council

Multi-agency management and oversight of SERDP continues to be one of the clear strengths of SERDP. Active participation by the members of the SERDP Council, their designated representatives on the EWG, and participation on the TTAWGs precludes duplication of effort, ensures quality Program content, and facilitates information transfer. This tri-parte arrangement, composed of executive, programmatic and technical individuals who represent the three primary participating organizations, yields a depth and breadth of knowledge and experience at several levels of management and technical expertise lending significant credibility to the Program.

On September 26, 2002, the SERDP Council approved the FY 2003 Program Plan and the FY 2004 Investment Plan. For FY 2003, SERDP was appropriated $54.6 million, which included funding for two congressional interest projects.

Multi-Agency participation is a clear strength of the Program.

The Council met one year later on September 30, 2003 to approve the FY 2004 Program. The President's Budget Request for SERDP for FY 2004 represented a decrease of $7.5 million from the FY 2003 appropriation. The Congressional appropriation for FY 2004 increased SERDP's budget to $50.6 million, which included two Congressional interest projects. The Council approved the FY 2004 Core program as presented. The Council further granted the Executive Director the authority to execute any Congressional interest projects that may be added to the appropriation to ensure they appropriately focused on defense issues. The Council reviewed and approved the FY 2005 investment guidance.

Executive Director and Program Office

Continued Emphasis on Unexploded Ordnance and Range Sustainability

In FY 2003, the Executive Director continued managing UXO as a separate Thrust Area. This is due to the significant technical challenges and potentially large liability for the DoD, its associated increase in the President's Defense budget to address UXO detection, and the fact that the technologies involved in UXO detection are discretely different than those used in conventional cleanup. SERDP will continue to coordinate its UXO research efforts with the DoD's Joint UXO Center of Excellence and keep abreast of new initiatives developed with the Counter Mine efforts, such as found within the Multiple University Research Initiative (MURI). Furthermore, the UXO Program plan undergoes a thorough peer review to ensure that it properly characterizes the broad problem, establishes clear and logical goals, and identifies specific, relevant, near-term technical objectives.

In response to a SERDP Council action item from the Council meeting in 2002, SERDP has developed a new investment strategy that frames research topic areas in terms of DoD priorities and is based on two major research areas. The first area is Sustainability of Ranges and Range Operations, which includes maritime sustainability, threatened and endangered species (TES), active clearance of unexploded ordnance, toxic air emissions and dust, urban growth & encroachment; and noise. The second area of the SERDP investment strategy is Reduction of Current and Future Liability which address (1) contamination from past practices and includes research on intractable chlorinated solvents; UXO cleanup; and new emerging contaminants such as ClO_4^- and (2) pollution prevention to control life cycle costs, which includes elimination of hazardous materials to reduce the cost of operation, repair & demilitarization and achieving compliance through Pollution Prevention. The large shift of SERDP investment to UXO detection and discrimination as well as the emphasis on range sustainability research across thrust areas over the past several years reflects SERDP emphasis on priority investment opportunities.

Proposal Solicitation and Selection

SERDP takes pride in the fact that funds for new starts are available to industry, academia and Federal researcher alike, and the Council continues to be pleased with SERDP's ability to reach out to a broader pool of researchers through a BAA. SERDP again extended two solicitations – a "Core" solicitation that has traditionally been used to develop the annual program and a SEED solicitation.

The SEED Program is designed to provide initial funding for high-risk, high-payoff proof-of-concept projects. Funding is limited to a maximum of $100,000 for up to one year. Successful efforts may compete for additional funds in the following years.

Technology Transfer

Successful technology transfer is used as a metric to measure the success of the Program. SERDP has funded over 400 individual projects. Several avenues are taken to ensure that the successful efforts of the research teams are transitioned to either higher development programs, such as ESTCP, or implemented directly into field use.

Technology transfer and transition continued to be a primary area of focus during annual project reviews by both the SAB and the TTAWGs. Principal investigators were tasked to prepare Annual Technical Reports that serve as a fundamental baseline of technical progress. At the end of each project, a Final Technical Report is required for each effort. These reports are maintained in a SERDP library and referenced on the SERDP website. Additionally, they are entered into the Defense Technical Information Center (DTIC) in both a hard copy and electronic version. DTIC provides all researchers with copies of these reports upon request. SERDP also continues to partner with the EPA ORD and the DoD's ESTCP.

SERDP has posted Fact Sheets on the website for every SERDP funded project. These Fact Sheets include summaries of the technical accomplishments and potential benefits of each project. The SERDP website also provides links to websites maintained by SERDP researchers that provide additional information about technologies developed under SERDP.

Each year, SERDP, in cooperation with ESTCP, hosts the *Partners in Environmental Technology Technical Symposium and Workshop*. This event has, for the past eight years, attracted hundreds of researchers, technology developers and users, and regulators to meet in a collegial and informative setting. In December 2003, the annual Symposium once again succeeded in providing an excellent technology transfer and networking forum for researchers, scientists, and engineers from both the Federal laboratory system and the non-Federal sector alike. Our venue focused on "Meeting DoD's Environmental Challenges Sustaining Our Ranges; Reducing Environmental Liabilities" in recognition of the fact that while significant advances have been made in addressing environmental issues, additional challenges to continue. This event brought more than 750 technology developers and implementers together, as well representatives from the policy, programmatic, regulatory, academic, and industrial sectors. The SAB Chairman issued the annual SERDP Project of the Year Awards, which were given to the best projects in each of the five Thrust Areas for FY 2003. These awards have successfully attracted the attention of the scientific and engineering community around the globe and have measurably helped to either transition this technology into higher development programs, or implement its use in field applications. This conference, which has received numerous accolades, will continue to be enhanced to serve as a significant technical, educational, and technology transfer event.

Plans for FY 2004

In FY 2004 SERDP will aggressively respond to the increasing challenges of environmental issues impacting training and testing activities as well as the remediation of lands contaminated with UXO. Specifically, in response to the President's FY 2004 budget request and subsequent Congressional changes, SERDP issued SONs to address the following issues:

- Innovative methods for measuring hydraulic conductivity; abiotic attenuation processes for chlorinated solvents; and remedial technologies for contaminated sediments; heavy metals in groundwater, and nitroaromatic compounds in soil and groundwater.

- Characterizing, monitoring, and evaluating the impacts of aircraft noise and impulse noise; NOx, PM, and toxic air emission from aircraft and PM emissions factors DoD activities.

- Control of invasive plant species, monitoring high-priority TES and quantifying physiological stress in TES, characterization of marine mammal behavior, and measuring terrestrial productivity and carbon budgets at Ft. Benning.

- Eliminating redwater from TNT manufacturing and environmentally acceptable alternatives to: cadmium plating on high-strength steels, solvents containing Class II ozone depleting substances, ammonium ClO_4^- in missile fuels, and incendiary compositions for medium caliber munitions.

- Advanced approaches for detecting and discriminating UXO, identifying filler material in recovered UXO, and characterizing and remediating underwater UXO sites.

In developing the FY 2004 program, 23 SONs were prepared, with none issued specifically for the SEED program. All 23 Core SONs, were made available to the private sector via a BAA. The Core solicitation resulted in 272 pre-proposals that were submitted by non-Federal participants. Of the 92 full proposals that were requested, 25 were selected for funding resulting in a 27 percent selection rate. This figure exceeds the Council's target of 20 percent and was much greater than that experienced in other programs, such as those funded by the National Science Foundation. The Federal sector submitted 124 full proposals of which 8 were selected for a 7 percent selection rate. Figure I-6 depicts the distribution of Core proposals selected during the FY 2004 program development process.

CORE PROPOSALS						
Thrust Area	No. of SONs	No. of Proposals Selected	SOURCE: Federal	SOURCE: Academia	SOURCE: Private	Approximate Value (Thrust Total)
Cleanup	5	7	1	4	2	$1.436
Compliance	5	2	0	0	2	$0.571
Conservation	5	2	1	1	0	$0.674
Pollution Prevention	5	4	2	0	2	$1.045
UXO	3	9	3	2	4	$1.859
Total	23	24	7	7	10	$5.585

Figure I-6. FY 2004 Core New Start Proposal Distribution by Thrust Area.

Other activities that SERDP plans to actively pursue in FY 2004 include:

- In early FY 2004, SERDP issued SONs for projects to be funded in FY 2005 (see Appendix F for full listing of SONs). Areas of interest for funding in FY 2005 include:

  – Cleanup - remediation of emerging contaminants; screening level assessment and treatment of explosives - and propellant-contaminated runoff from training ranges; screening levels and toxicity reference values for risk assessments; and improved understanding of in situ thermal treatment.

  – Compliance - characterization and fate of the source term of energetic compounds in aquatic environments; environmental fate and transport exposure assessment for energetic materials on ranges; identification and characterization of natural sources of ClO_4^-; improved methods and monitoring systems for impulse noise; and treatment of ClO_4^- in waste water.

  – Conservation - identification of DoD vectors for non-indigenous species transport; advanced monitoring strategies for migratory birds on military lands; terrestrial biogeochemical cycle models for Fort Benning ecosystems; improved remote sensing of threatened and endangered species and habitats.

  – Pollution Prevention - hazardous air pollutant (HAP)-free solvents for DoD cleaning applications; alternatives for ClO_4^- in incendiary mixes and pyrotechnic formulations; and environmentally benign medium caliber gun barrels.

  – UXO - site characterization and remediation technologies for UXO contaminated underwater sites; dual-mode navigation for portable platforms; magnetometer or EMI sensors and processing; and UXO systems integration study.

- SERDP will continue conducting special studies and gap analyses to identify future opportunities for research and potential opportunities for integration/collaboration to address unmet high-priority research needs.

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II. SIGNIFICANT ACCOMPLISHMENTS

Introduction

SERDP continues to be a leader in the field of environmental research and development by providing solutions to both new and persistent priority environmental matters of concern to the DoD and the DOE. With an effective outreach program that includes technology gap analysis studies, SERDP strives to remain ahead of the curve on identifying high-priority and emerging environmental technology requirements. SERDP has supported hundreds of science and technology projects since the Program's inception in 1991 in the areas of cleanup, compliance, conservation, pollution prevention, and unexploded ordnance. These projects have enabled DoD installations to meet their environmental responsibilities using cost-effective and innovative methods. During FY 2003, SERDP continued to play a critical role in the development of science and technology that supports the DoD's environmental security mission.

A selection of SERDP's most significant accomplishments during FY 2003 are described in this section. While these projects represent but a small slice of the many innovative projects supported by SERDP, they demonstrate the breadth and depth of the program and highlight the types of major technical advances resulting from focused research and development. Moreover, many of these accomplishments illustrate potential cost savings resulting from full implementation of new technologies while simultaneously maintaining military mission readiness. Appendices A through F provide a summary of all SERDP projects funded in FY 2003, new projects funded for FY 2004, and new initiatives planned for FY 2005.

Cleanup Accomplishments

Range Sustainability - Treatment of Energetic Materials

The use of munitions is an integral part of the military's testing and training. Energetic materials that are used in these munitions and that are of primary environmental concern include 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX). These compounds have been identified in the soil and groundwater at former and current ammunition manufacturing sites as well as at military testing and training ranges. Challenges facing those involved in cleanup include developing appropriate remedial actions to address site contamination and treating the contaminated soil and groundwater to ensure compliance with established cleanup standards.

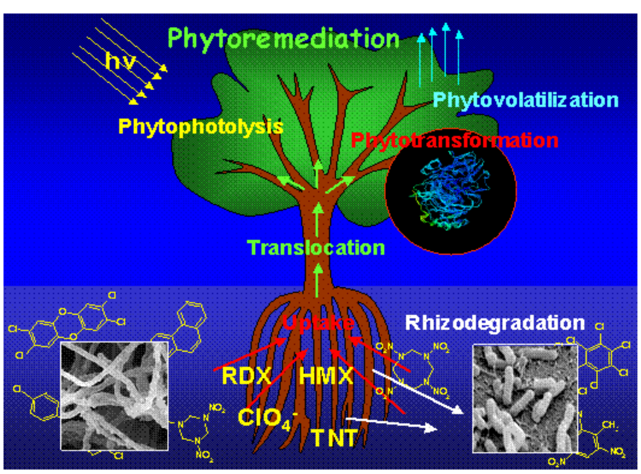

Figure II-1. Fate and Transport Processes Involved in Phytoremediation.

Phytoremediation is gaining interest as a cost-effective and versatile technology to remediate groundwater and surface soil that is contaminated by energetic materials. Phytoremediation potentially can be used as a remediation technology for historically contaminated sites and as a preventive technology for sites that will be used for military testing and training in the future. In applying phytoremediation to energetic materials, there are several questions that require further investigation. The fate of contaminants once they have been taken up into the plant tissue is uncertain (Figure II-1). These plants may enter the food chain via consumption by other organisms or eventually degrade into the soil. Therefore, the issue of "pollution transfer" remains a serious concern with phytoremediation. In addition, the rates of degradation vary greatly among energetic

materials. There exists the potential to identify and promote plant genes that degrade energetic materials to benign products. Three complementary SERDP-funded projects are investigating these fundamental aspects of phytoremediation for energetic materials. Collaboration began with a site visit by the lead researchers for these projects to Eglin AFB in Florida during September 2002 to increase their familiarity with DoD's needs.

The SERDP project, **Genetic and Biochemical Basis for the Transformation of Energetic Materials (RDX, TNT, dinitrotoluene [DNTs]) by Plants (CU-1319)**, is constructing a genetic and biochemical knowledge base for the transformation pathways of energetic materials by exploiting the fact that these materials are phytotoxic. Researchers at Iowa State University are in the process of identifying the genes that are responsible for the metabolism of energetic materials by using mutants of a model mustard plant, *Arabidopsis thaliana*. Mutants are defined as those resistant to the energetic materials. In FY 2003, the researchers established a library which contains genetic information on the mutant *Arabidopsis* plants. The specific metabolic function of these genes is now being explored. The results of this research will be incorporated into the other two SERDP-funded phytoremediation projects (CU-1317 and CU-1318) and will facilitate the selection of beneficial plant species, metabolic engineering of transgenic plants, environmental impact assessment of suspected energetic materials-contaminated media, and the design of phytoremediation processes for the treatment of energetics-contaminated media.

Researchers from the University of Iowa, under the SERDP project **Identification of Metabolic Routes and Catabolic Enzymes Involved in Phytoremediation of the Nitro-Substituted Explosives TNT, RDX, and HMX (CU-1317)**, are investigating the metabolic routes and catabolic enzymes that are involved in the transformation and detoxification of TNT, RDX, and HMX using poplar trees. A secondary objective is to research the toxic effects of these explosives once they are taken up inside of the poplar tree tissues. By using small whole plants, researchers have discovered that TNT, RDX, and HMX can all be actively taken up by plants from a hydroponic solution. However, in these experiments, the uptake of TNT was significantly higher than the uptake of RDX and HMX. TNT has been shown to accumulate in the roots of the plant, while RDX and HMX accumulate in the leaf tissues. While the identification of metabolites that are generated by the degradation of RDX, HMX and TNT is an ongoing process, researchers have already discovered that the metabolism of these explosives generally produces reductive derivatives that are significantly less toxic than the original compounds. In FY 2003, the team also discovered an endosymbiotic bacterium, *Methylobacterium*, that has been shown to metabolize toxic explosives. Plans have been made to further research the impact that this bacterium could have on the degradation of TNT, RDX, and HMX. Research to date supports the use of poplar trees to treat soils contaminated with these energetic compounds.

In a third project, **Engineering Transgenic Plants for the Sustained Containment and In Situ Treatment of Energetic Materials (CU-1318)**, researchers from the University of Washington and the University of York are endeavoring to engineer transgenic plants that have the structural and biological capabilities to contain and degrade energetic materials found on military testing and training ranges. Beginning in FY 2002, the researchers have selected and modified two bacterial genes that can utilize and degrade RDX. Expression of these genes in tobacco as a model plant system have been successful. Studies are also being performed to compare the maximum amount of TNT and DNT concentrations that wild plants versus genetically altered plants can tolerate. Research on the prevalence of root hairs has revealed that they are a good indicator of plant health. Even though the presence of TNT has proven to be toxic to the plant's growth and affects the formation of root hairs on the plant, the genetically altered plants tended to show more root hair growth than the wild plants (Figure II-2). Future plans include

Figure II-2. In the Laboratory, Non-Transgenic Plants Extracted Very Little TNT and the Toxic Effects Were Clearly Visible (left) While Transgenic Plants Displayed Minimal Signs of Phytotoxicity (right) and Removed All of the TNT.

introducing the genes that utilize and degrade RDX into poplar, black locust, and aspen plant varieties for eventual use at testing and training ranges.

Other SERDP-funded projects are investigating additional in situ technologies to remediate groundwater and soils contaminated with energetic materials as alternatives to long-term pump and treat. **Fe^0-Based Bioremediation of RDX-Contaminated Groundwater (CU-1231)** is a FY 2003 completing project that successfully developed an efficient method to remediate RDX-contaminated aquifers by coupling the biogeochemical interactions of zero-valent iron and microorganisms. Because of its mobility in groundwater, RDX represents a major remediation challenge at numerous military facilities. This project was originally funded as a one-year SEED project; however, because of its success, it was later funded as a multi-year SERDP project. During the original phase of the project, researchers from the University of Iowa performed microcosm studies that revealed a synergistic interaction between Fe^0 filings and municipal anaerobic sludge. When combined, 51 percent mineralization of RDX was observed as compared to 22 percent for zero-valent iron alone and 29 percent for bioremediation alone (all in the presence of soil).

Based on extensive batch and flow-through column studies, researchers have concluded that permeable reactive iron barriers (PRBs), with the aid of microorganisms, are able to effectively intercept and degrade RDX in groundwater (Figure II-3). To gain a better understanding of the potential benefits of bioaugmentation, researchers examined the limiting factors of several different bacterial groups, each of which played a valuable role in the removal of RDX from the groundwater. Altogether, the results indicate that biogeochemical interactions are an exciting frontier for bioremediation. The concept developed in this project is now being demonstrated in the ESTCP at Cornhusker Army Ammunition Plant in Nebraska.

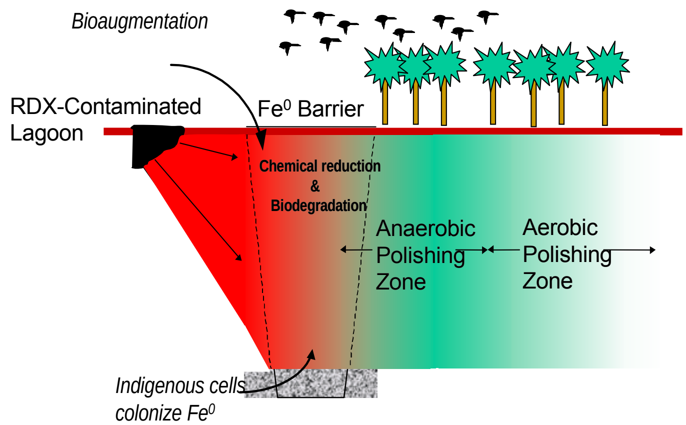

Figure II-3. Iron-Based Bioremediation with Polishing by Natural Attenuation.

Contaminated Sediments

Marine and freshwater sediments are the ultimate receptors of contaminants in effluent from urban, agricultural, industrial, and recreational activities, both at sea and on shore. As a result of past activities, sediments exhibit some level of impact from anthropogenic compounds. As marine sediment and coastal sites fall under increasing scrutiny, the number of sites for which ecological risk assessment and management will be deemed necessary is likely to increase. Polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), contaminants of environmental concern, become mixed with sediments and enter the food chain via accumulation in bottom-dwelling organisms. DoD site managers are particularly interested in in situ technologies that allow for the remediation of contaminated sediments without the costly and potentially ecologically damaging removal of these sediments.

In the SERDP project **In Situ Stabilization of Persistent Organic Contaminants in Marine Sediments (CU-1207)**, researchers from Stanford University and the University of Maryland sought to determine the feasibility for in situ stabilization and containment of PAHs and PCBs in marine sediments. Research was conducted to determine if the contaminants could be contained and bioavailability reduced using inexpensive

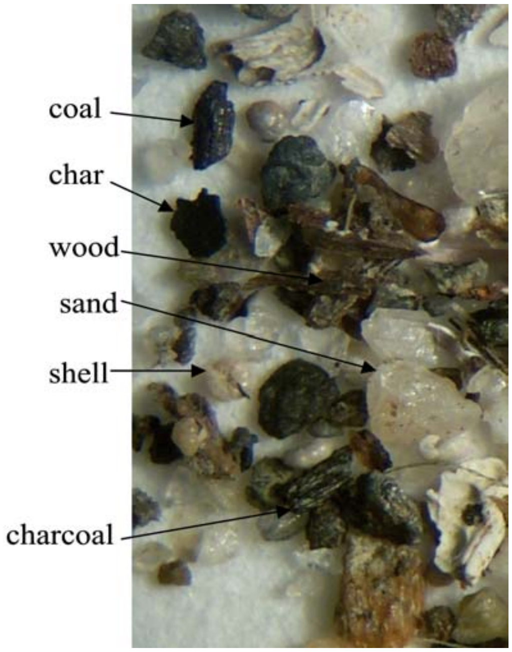

Figure II-4. Hunters Point Sediment (63-350 µm).

coal-derived materials, such as coke. Past research funded by SERDP demonstrated that coal-derived products were potentially good sorbents for this purpose.

The research team characterized the sediment at Hunter's Point Naval Shipyard in San Francisco, California and found that the heavier components of the sediment (made up of silt/ sand/clay) comprised the bulk of the material but contained only a limited number of PCBs and PAHs. The lighter component of the sediment (consisting of coal/charcoal/coke/ wood) comprised only 6 percent of sediment mass but contained 68 percent of PCBs and 89 percent of PAHs (Figure II-4). The research team believes that over time the contaminants naturally transfer from the sediment to the carbonaceous particles like charcoal, coke, and wood. Researchers also found that the treatment of contaminated sediments with carbon sources significantly reduced the bioavailability of the contaminants in clams, worms, and other aquatic organisms. Final results of this completing project indicate that the in situ addition of carbonaceous sources is a promising method for remediation of contaminated sediments. Plans for future pilot-scale studies are already underway.

Ecological Soil Screening Levels

Ecological soil screening levels (Eco-SSLs) are contaminant concentrations in soil which, when not exceeded, will protect terrestrial ecosystems from unacceptable harmful effects. Eco-SSLs are based on data generated by laboratory toxicity tests for many organisms that represent the vast array of naturally occurring ecological receptors. Research has shown that the bioavailability of contaminants to organisms in soil and other media is substantially less than 100 percent. Existing Eco-SSLs generally assume that all of the contaminants are bioavailable to invertebrates and plants. However, the bioavailability of contaminants to organisms in soil and other media is affected by a vast array of physical, chemical, and biological modifying factors. To screen contaminated sites for the ecological risk assessment process, it is necessary to develop rapid, inexpensive, routine methods for measuring the expected bioavailability of soil contaminants to plants and invertebrates. SERDP has funded a number of projects and released a SON in FY 2005 for proposals that address the collection of these data to assist in the development of Eco-SSLs for plants, invertebrates, and wildlife for contaminants in soils at DoD facilities.

The SERDP project **Biological Assessment for Characterizing Contaminant Risk at the Genetic-, Individual-, and Population Level (CU-1129)**, sought to develop a rapid and cost-effective approach for assessing the impacts of military-relevant contaminants in water, sediment, and soil, that could be used to quantify ecological risk at the genetic, individual, and population level. Researchers spiked sediments with RDX, HMX, and TNT and then exposed organisms to the contaminated sediments (Figure II-5). The organisms and sediments were then screened for the presence of the contaminants using genetic testing. Finally, researchers from the U.S. Army Corps of Engineers

Neanthes Arenaceodenta

Leptocheirus plumulosus

Chironomus tentans

Figure II-5. Examples of Ecological Receptors Investigated to Assess the Impacts of Military-Relevant Contaminants in Soils.

- Engineer Research and Development Center - Environmental Laboratory, evaluated the overall effects of the contaminants on the survival, growth, and reproduction of each species.

Researchers found that RDX and HMX in water and sediments did not decrease invertebrate survival rates even at high concentrations. In contrast, TNT and trinitrobenzene (TNB), a photodegradation product of TNT, were found to be toxic, while TNT degradation products were less toxic, depending on the degree of degradation. Results from this investigation indicate that TNT and its daughter compounds interact additively when in a mixture. These results indicate that the toxicity of a mixture of TNT compounds for a given receptor can reasonably be predicted using single-compound toxicity derived for that receptor. Researchers also investigated the bioaccumulation of TNT in aquatic organisms, and found that increases in TNT and DNT in water and tissue concentrations decreased the survival rate of the organisms. The team developed genetic assays to assess the effects of contaminants on benthic invertebrates and to better understand the effects of the contaminants on a cellular level. The combined results of the research are contributing to an increased understanding of contaminant bioavailability, the toxicity of military unique compounds, and the toxicity of complex mixtures of these compounds.

Another SERDP project, **Determining the Bioavailability, Toxicity, and Bioaccumulation of Organic Chemicals and Metals for the Development of Eco-SSLs (CU-1210)**, investigated how the chemical bioavailability and toxicity of contaminants to invertebrates and plants is altered by the soil's physical and chemical properties. Researchers at Ohio State University also sought to determine how bioavailability could be measured in soil systems for compounds like PAHs, TNT, RDX and metals such as cadmium, arsenic, and zinc (Zn). After performing toxicity and bioaccumulation tests using varying types of soils with several different invertebrates, researchers have determined that TNT toxicity varies with soil type. TNT was shown to be less toxic to earthworm reproduction in soils that had a high organic material content and high clay content. In addition, the data indicate that the amount of organic material in a soil plays a more significant role in the toxicity to organisms than the clay content. In contrast to the results for TNT, there were no distinct differences in recovery rates between low and high nominal concentrations of RDX. Initial studies have also shown that perylene, a PAH, was non-toxic at the maximum amount of perylene that could be amended to the soil due to solubility constraints. These tests were conducted in a sandy soil presumed to represent maximum chemical bioavailability. Therefore, perylene appears to be non-toxic at concentrations represented by the maximum solubility in acetone. The data derived from this project will facilitate the further development of Eco-SSLs that take into account science-based estimates of bioavailability when evaluating ecological risk.

Initiatives to Address Chlorinated Solvents

Chlorinated solvents are by far the most prevalent contaminants at DoD facilities. A recent estimate indicates that DoD owns more than 3,000 sites contaminated with chlorinated solvents in the U.S. alone. Many sites have chlorinated solvents as dense non-aqueous phase liquids (DNAPL) in the subsurface that serve as long-term sources of dissolved-phase groundwater contamination (Figure II-6). Complete cleanup of these sites historically has been considered technically impracticable; therefore, the typical response has been containment by pumping and treating contaminated groundwater. New technologies designed to remove the subsurface sources of DNAPLs have received tremendous interest. Examples include thermal treatment, chemical oxidation, bioremediation, and enhanced physical removal (e.g., using cosolvents or surfactants). Under appropriate conditions, these technologies can remove a large fraction of the total DNAPL mass. However, there is uncertainty regarding the benefits of using such technologies. Key questions for site managers include: (1) are the costs for source removal technologies

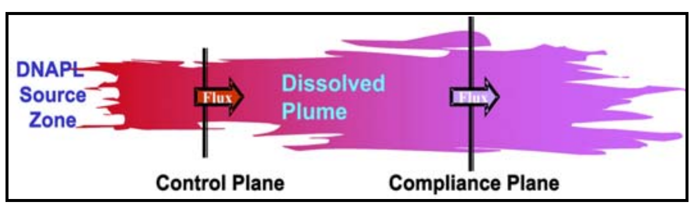

Figure II-6. Hypothetical DNAPL Source and Dissolved Plume.

justified in terms of the reduced need for or duration of active containment of the groundwater plume; (2) how much source removal is required to cease active containment at a given site and to ensure protection of human health and the environment; and (3) will contaminants migrate outside of the treatment zone?

In FY 2002, SERDP released two SONs to specifically address this issue. The first SON requested proposals to develop an increased understanding and characterization tools to better assess the need for and impacts of DNAPL source zone treatment technologies. The second SON sought proposals to gain an improved understanding of the potential and limitations of in situ chemical oxidation (ISCO) for the destruction of DNAPLs (Figure II-7). Four complementary projects were funded within each SON.

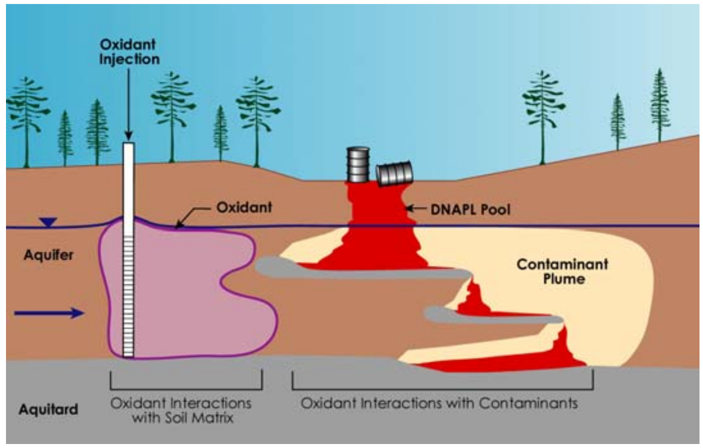

Figure II-7. Application of ISCO at the Field-Scale.

To encourage a high level of cooperation and coordination between PIs working on these efforts, SERDP formed two independent Technical Review Panels - one for the DNAPL Source Zone and one for ISCO. The Panels are composed of one Chair and four members, all renowned experts in the field, who meet twice each year. The panel members provide suggestions and guidance to help facilitate the collaboration and sharing of information between these projects. Members of the panels also help to identify gaps in DNAPL Source Zone and ISCO research and provide suggestions for the development of future SONs. The final goal of the DNAPL Source Zone initiative is to make available to the user community a suite of tools for assessing the impacts of source zone treatment; whereas, the goal of the ISCO initiative is to develop a protocol that can be used to guide future implementation of this technology in the field. Through collaboration and expert oversight, it is anticipated that progress in addressing the issue of chlorinated solvents will advance in a comprehensive and expeditious manner.

Compliance Accomplishments

Air Emissions of Energetic Materials

Military ranges are under increasing public scrutiny with respect to the potential environmental hazards to nearby communities. A group of potential hazards includes toxic emissions from the use of munitions during training and testing activities. The Emergency Planning and Community Right-to-Know Act (EPCRA) requires industry and government agencies to report emissions of chemicals listed on the Toxic Release Inventory (TRI). This requires that DoD address toxic release inventory requirements. DoD facilities, specifically testing and training ranges, need reliable data on air emissions of TRI chemicals from munitions activities to (1) meet EPCRA reporting requirements and/or (2) demonstrate that emissions are below *de minimis* concentrations which means they would not need to be reported. Therefore, DoD requires the technology for estimating emission factors for TRI chemicals from munitions used during testing and training activities.

To meet this need, SERDP project **A Field Program to Identify TRI Chemicals and Determine Emission Factors From DoD Munitions Activities (CP-1197)**, led by Battelle Memorial Institute, is developing, evaluating and applying approaches to determine the TRI chemical emissions discharged by munitions under realistic conditions. Researchers conducted an extensive literature review of past studies of munitions emissions, and reviewed the compositions of numerous munitions items to select target TRI chemicals for measurement. The team identified 124 TRI chemicals or chemical groups as potential emissions from

munitions. Following the identification of potential target chemicals, a modeling analysis to estimate the detection limits that will be needed to measure the target chemicals under realistic conditions on a testing range was performed. Based on this analysis and the estimated detection limits of the potential measurement methods, 6 measurement methods and 75 TRI chemicals for measurement during emissions testing were identified. The types, usage, and chemical composition of a large number of munitions items were reviewed and the information was used to identify and prioritize items for emissions testing.

Researchers are conducting two types of field campaigns. One is quantifying TRI emissions from the point of weapons discharge, and the other is measuring emissions from the detonation of munitions on impact. One of the objectives of the point of discharge (POD) study was to compare the project's measurement methods with accepted standard methods of the EPA and National Institute for Occupational Safety and Health, which often involve collecting large air sample volumes for a duration of several minutes. Because the ultimate objective of the project was to quantify emissions in uncontrolled outdoor situations, where only a few seconds may be available for sampling, researchers selected and developed several fast-response, high sensitivity, real-time measurement approaches. Results of a data comparison for four chemicals (total carbon, formaldehyde, benzene, and copper [Cu]) showed solid agreement between the project's novel methods and the standard methods, providing credibility for the novel methods used for the point of impact (POI) studies.

The POI tests required measurements of the concentrations of numerous chemicals in a relatively small, moving cloud of emissions, and either accurate measurements of a stable tracer chemical that was distributed in the cloud in the same manner as the target chemicals, or accurate estimates of the volume of the emissions cloud at the time of sampling. Since these tests were performed outdoors on a test range, where variable meteorology is a factor, a considerable effort during this project has been focused on understanding the behavior of an emissions cloud following the detonation of an ordnance item, and devising a strategy that would provide the greatest chance of success for measuring TRI chemicals in that cloud with sufficient sensitivity to calculate emissions factors, and for measuring the volume of the cloud (Figure II-8). The data from the POI campaign are currently being analyzed. Emissions exposures to the large number of TRI chemicals from artillery and mortar armaments and in exploding ordnance can now be determined. This will allow the military to address the potential hazards to military personnel and determine the need for new environmentally compliant munitions.

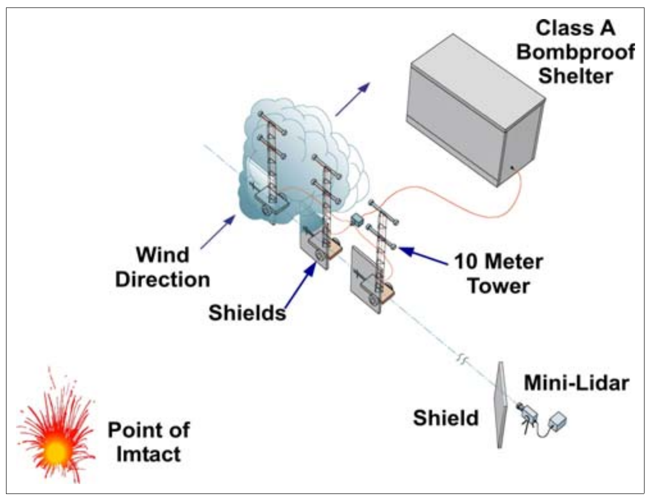

Figure II-8. Plume Measurement During POI Field Campaign.

A related issue of public concern is the potential environmental consequences caused by munitions emissions, and meeting regulatory compliance requirements is open burn and open detonation (OB/OD) operations used by DoD to destroy excess, obsolete, or unserviceable munitions and energetic materials. Underlying soil, nearby vegetation, surface and/or groundwater water may become contaminated with byproducts of incomplete combustion, heavy metals, or incomplete detonation products resulting from these operations.

The goals of SERDP project **A Predictive Capability for the Source of Terms of Residual Energetic Materials from Burning and/or Detonation Activities (CP-1159)** are to: (1) understand and quantify the major chemical and physical processes associated with OB/OD, such as afterburning effects and the formation and deposition of particles; (2) develop a detonation Source Characterization Model (SCM) that predicts potential air and ground water pollutants resulting from the burning and detonation of munitions, including

both gaseous and particulate species; (3) link the model output to appropriate fate and transport models in air, soil, or water; and (4) validate the final model against a few typical scenarios.

The SCM draws on new databases that compile munitions compositions and detonation products developed by collaborating scientists at the Army Environmental Center. It is designed to predict the chemical content of the detonation fireball, compute the mass of fireball entrained soil particles, estimate the amount of shock dissipated energetic material that escapes beyond the fireball, and model the entrainment of atmospheric oxygen mixed into the fireball and the subsequent afterburning effects on the chemical content of the detonation plume. It can also be used to predict the chemical interactions among both gas phase pollutants and soot and dirt particles in the plume, calculate the deposition pattern of larger plume entrained particles back to the surface, and predict the buoyant rise of the plume gases and entrained fine particles.

The detonation model has been validated with pollutant emission factor data obtained for a variety of munitions and demolition charges obtained in an on-going series of detonation tests managed by the Army Environmental Center. After validation against a sufficient range of diverse munitions and explosives, the SCM can be used to predict emissions factors for as yet unmeasured types of munitions. These emissions factors can be used as inputs for traditional atmospheric dispersion or soil and ground water transport models that may be used by environmental scientists and engineers to predict the impact of military training, weapons testing, or munitions disposal activities on military facilities and surrounding regions.

The collective results of these advances in air emissions monitoring technologies combined with innovative air emissions treatment technologies will help ensure that DoD will continue to maintain military readiness while complying with stringent air pollution regulations.

Marine Environmental Issues – Affects of Cu and Zn on Estuaries

Cu and Zn have for years been used as primary constituents in ship bottom paints and coatings and electrolytic devices. The result is that these metals are prevalent in the sediments in harbors and in-land waterways. Many industrial and non-point source effluents, in addition to discharges from DoD facilities, ships, and small craft, can also release Cu and Zn into the marine environment. Some of these heavy metal molecules are dissolved in the surrounding water, becoming bioavailable and toxic to marine organisms. Traditional water quality measurements use total metal concentration as a metric for regulatory standards. However, studies indicate that total metal concentration may greatly over-predict the toxicity or potential risk to the environment. On the other hand, the amount of bioavailable metal correlates directly to toxicity and risk. A fundamental understanding of the relationships between Cu and Zn sources, the concentrations of these metal species, and their bioavailability are needed to properly define future approaches to Cu and Zn regulations. SERDP-funded research is making significant strides in developing this understanding.

In order to examine the distribution, fate, and toxicity of Cu and Zn from DoD-related sources, SERDP has funded three collaborative projects. Most notably, these projects have agreed upon a common sampling and analysis protocol for measuring Cu and Zn speciation in three marine estuaries -- San Diego Bay (CA), Cape Fear River (NC) and Norfolk Harbor (VA). Each of these projects have contributed significantly to the understanding of Cu and Zn in estuaries. The SERDP project **Speciation, Fluxes, and Cycling of Dissolved Cu and Zn in Estuaries: The Roles of Sediment Exchange and Photochemical Effects (CP-1157)** has revealed the potentially important role of sediment-water exchange as a source of strong complexing organic or binding compounds (known as ligands) that control the speciation of these two potentially toxic metals in estuarine and harbor environments. Researchers from the University of North Carolina in Wilmington have determined that Cu speciation in some estuaries and harbor environments may be roughly predicted by measuring dissolved organic carbon, a relatively easy to measure parameter. The Cape Fear Estuary in southeastern North Carolina has a significant excess of very strong Cu-complexing organic compounds relative to the amount of ambient dissolved free Cu. Hence, the Cape Fear Estuary may be considered to be relatively “well-buffered” with respect to potentially toxic free Cu because of these ligands. Researchers have

detected movement of Cu-complexing ligands from sediments into the overlying water column. Most of the strong Cu-complexing ligands are derived from the very small size fraction of the sediment. This observation contrasts with previous observations in less organic-rich estuaries, in which most Cu-complexing ligands were found to be dissolved in the water column. The photochemical reactivity of dissolved Cu and Cu-complexing ligands in the Cape Fear Estuary also is being examined. Results indicate that a significant fraction (~20%) of Cu-complexing ligands degrade under solar irradiation. However, a class of extremely strong ligands was apparently not degraded. These and other experiments suggest that very strongly complexed Cu may not be photoreactive, whereas weaker complexes may be more photoreactive, resulting in the release of Cu with exposure to sunlight.

The overall goal of the SERDP project **Speciation, Sources, and Bioavailability of Cu and Zn in DoD Impacted Harbors and Estuaries (CP-1158)**, led by researchers from the University of Wisconsin in Madison, is to advance the current understanding of the fate and impact of Cu and Zn in harbors and estuaries as a result of DoD activities. Studies found that the amount of Cu uptake in algal cells, a measure of bioavailability, directly correlates to the presence and quantity of Cu-binding complex ligands in the three marine estuaries. The lability (i.e., reactivity) of Cu and Zn within "pools" or sinks in which these trace metals can accumulate (e.g., sediments) has been characterized using several complementary techniques, including electrochemical and resin-based methods. The result is that the bioavailability of Cu in specific pools was determined with three species of marine algae using both molecular and whole organism bioassays. These bioavailability studies indicate that Cu uptake into algal cells can be accurately predicted from concentration of strong ligand, and therefore these results strongly support efforts to develop speciation-based water quality criteria for Cu and Zn.

The above two projects (CP-1157 and CP-1158) were jointly awarded the FY 2003 SERDP Compliance Project of the Year Award at the *Partners in Environmental Technology Symposium and Workshop* held December 2-4, 2003.

The SERDP project **Determining the Fate and Ecological Effects of Cu and Zn Loading in Estuarine Environments: A Multidisciplinary Approach (CP-1156)** developed a method for estimating the ecological impact of Cu and Zn loading on estuarine environments, specifically in mixing zones within the San Diego Bay. This effort, led by the Navy Space and Naval Warfare Systems Command (SPAWAR) Systems Center in San Diego, applied a hydrodynamic (physical) estuarine model that simulates estuarine topography, tidally-driven currents, meteorology, and bottom characteristics (Figure II-9). The model was modified to compute water residence times for Cu and Zn species in the estuary, the key physio-chemical variable against which all other rate-dependant processes are evaluated. Results indicate a relationship between toxicity and the capacity for ligands to complex with Cu. The results also indicate that the distribution of total Cu and complexed Cu in San Diego Bay is a direct function of the residence time of the water in the bay; the longer the residence time, the more Cu is complexed with available ligands. Modeling results indicate that tidal flushing and sedimentation are of roughly equal importance in the overall concentration of total Cu in San Diego Bay.

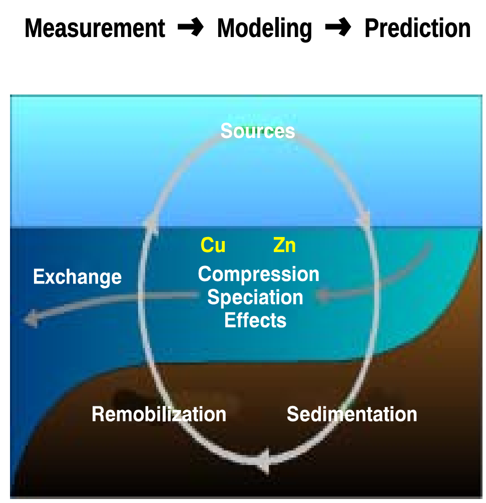

Figure II-9. Partitioning of Estuarine Copper and Zinc among Reservoirs at Steady State.

The collaborative research conducted by these three projects substantiate that accounting for metal speciation in estuaries will enable a more realistic estimation of acute and chronic risk for these metals, and these results will ultimately lead to development of scientifically-based water quality standards for Cu and Zn in the aquatic environment. With these data, DoD can evaluate their water quality compliance criteria and more accurately assess their potential impact on the harbor biological environment.

Marine Environmental Issues – Non-Indigenous Species from DoD Vessels

The proliferation of non-indigenous aquatic species is a recognized threat to the ecology of aquatic environments worldwide. Mitigation and control efforts along U.S. coasts have cost more than two billion dollars annually. Ship ballast water is thought to represent the primary vector of marine non-indigenous introductions in the U.S. and elsewhere (Figure II-10). There is concern that existing and proposed regulatory measures designed to control such introductions could translate into severe restrictions for DoD vessels, unless this aspect of ship operations is more fully characterized and managed.

Figure II-10. DoD Vessels, Such as the Oiler and Amphibious Transport Pictured Here, May Transport Non-Indigenous Species to Unaffected Bodies of Water Upon Discharge of Ballast or When the Ship Is in Port.

Two SERDP projects are currently being funded to provide collaborative research to develop a better understanding of the role that DoD operations may play in the introduction of invasive aquatic species. The study is focused on the Norfolk and San Diego Naval Stations, and the vessels sampled include oilers and cargo vessels operated by or for the Military Sealift Command. The sampling plan concentrates on the size fraction of planktonic organisms that includes common aquatic invertebrates for which invasions are well documented.

The primary means currently recommended to mitigate organism transport via ballast water is the exchange of resident water, often of coastal origin, with that of open ocean water. The vessels sampled in this study have consistently carried out some form of this management strategy and onboard physical data collected from ballast water appears to corroborate an ocean source for ballast water. Researchers expect the abundance and diversity of organisms in ballast water to vary with the type of vessel, destination and home ports, season and year, and have designed a sampling scheme to quantify this variation.

SERDP project **Characterization of Aquatic Non-Indigenous Species for DoD Vessels (CP-1245)**, led by Naval Surface Warfare Center, Carderock Division, is responsible for the sampling component of this study. Additional objectives are to quantify the abundance and diversity of organisms populating the ballast tanks and hulls of DoD vessels operating on the Atlantic and Pacific coasts and relate these findings to operational and maintenance histories and management practices. The sampling plan for this study is based on four key areas: (1) review vessel engineering logs to track ballast volume, sources, and management practices; (2) examine the physical and chemical characteristics of ballast water, such as temperature, salinity and dissolved oxygen; (3) quantify planktonic biota community structure/concentration; and (4) perform statistical analyses of the relationship to ship type, year, management practices, and physical/chemical characteristics. Researchers have developed a comprehensive decision tree for choosing ships and ballast tanks for sampling. The concentration and diversity of organisms in the sampled ballast tanks were related to the physical and chemical characteristics of the ballast water, where and when the ballast was loaded, conduct of management practices, type of vessel, and season and year. Researchers have currently sampled 16 vessels, 6 on the east coast and 10 on the west coast.

In addition, researchers evaluated the effect of hull coating characteristics, maintenance practices, vessel type, and location of home port on the occurrence of fouling. Analysis of maintenance practices, vessel and hull coating type will be conducted for Navy vessels using the hull inspection database maintained by the Naval Sea Systems Command. A remotely-operated vehicle was used to quantify the extent of fouling on ships' hulls, while divers collect qualitative samples to generate estimates of species richness for the fouling community, and determine whether non-indigenous species are present.

The SERDP project **Harmful Algae, Bacteria, and Fauna Transported by DoD Vessels (CP-1244)**, led by researchers from the North Carolina State University, developed innovative sampling and handling procedures to analyze ballast water with an emphasis on harmful algae, planktonic bacteria, and microfauna, and to determine the types and quantities of harmful microbial organisms transported by DoD vessels that may pose environmental or public health risks. Phytoplankton taxa identification and enumeration assessments have been completed for 13 of the 16 vessels sampled thus far. Identification of species have been achieved in most cases, and assignment to major phytoplankton taxonomic groupings has been made in all cases.

In addition, selected harmful species that were detected during these evaluations are being exposed to an experimental heat regimen to assess the potential of waste engine heat as means of ballast water treatment. The data are being used to help determine the most efficient, effective heat treatment regimen for eliminating undesirable phytoplankton from ballast water. As an example of the heat treatment experimentation, researchers examined thermal tolerance of the dinoflagellate *Prorocentrum triestinium* cultured from ballast water samples, and found a positive correlation between varying temperature/duration of heat exposure and species mortality.

Finally, a relational database is being developed for data organization, storage, and export for statistical analyses and for use in risk assessments. The database is being linked to a taxonomic image library and is designed to provide data for GIS mapping for several of the vessels that provided adequate data coverage and will be instrumental in helping to describe patterns in abundance and diversity at the end of the study.

The results of these two collaborative SERDP research projects are filling a critical data gap by providing information on the abundance and diversity of aquatic species found in ballast waters from DoD vessels. The characterization of the biological communities in the ballast water of DoD vessels, including "harmful" or invasive species, will assist the DoD in determining the measures necessary to reduce the risk of non-indigenous species introduction to U.S. harbors and estuaries by ballast water. This effort will lead to the development of cost-effective, environmentally-compliant treatment and monitoring technologies or management strategies, designed to control the spread of invasive organisms and meet the unique operating requirements of DoD vessels without jeopardizing operations or ship safety.

Conservation Accomplishments

Forecasting Impacts of Encroachment

Increasing urban growth and the resultant patterns of development outside some military installations are arguably having an impact on the military's ability to maintain focus on its mission. Some military installations' economic and environmental contributions to the local community are becoming less valued when compared to perceived incompatibilities such as noise, dust, resource competition, land use, land value, and land availability. These issues arise as local communities expand and available shared resources become scarce.

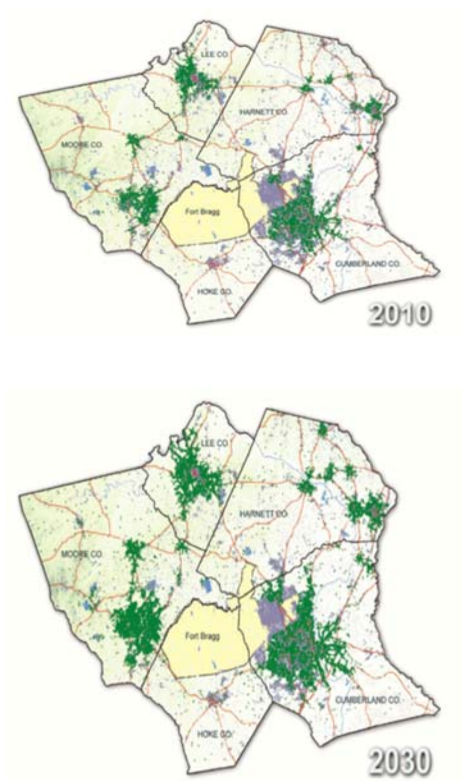

Figure II-11. Simulated Population Growth in the Area Surrounding Fort Bragg Using mLEAM.

To address these concerns, SERDP is funding a project entitled **The Evolving Urban Community and Military Installations: A Dynamic Spatial Decision Support System for Sustainable Military Communities (CS-1257)**. This project is evaluating possible future threats from urbanization to military installations and to mission fulfillment using a visually-based dynamic spatial decision support system (SDSS). A military version of the Land use Evolution and impact Assessment Model (mLEAM) developed by this project will simulate projected land use change around installations and assess the mission-related, economic, societal, and environmental impacts associated with the change (Figure II-11). The model is being applied to and tested on the Fort Benning/Columbus, Georgia corridor. The application of the SDSS that builds on the Fort Benning work will be made available to other at-risk military installations.

In FY 2003, economic drivers for development and their associated impacts on the installation were assessed and included as an economic input/output engine to mLEAM. In addition, a habitat fragmentation model will soon be added to mLEAM that describes changes to critical habitat due to urban transformation. Additional indices of the environmental impacts (e.g., water quality and noise impacts) related to installation/community economic, environmental and social interactions will be modeled and incorporated into mLEAM in FY 2004 and 2005. By projecting possible future areas of concern with surrounding communities, military planners will be able to develop proactive strategies that improve the overall viability and sustainability of their installations.

Threatened, Endangered, and At-Risk Species

DoD installations are required to inventory and monitor TES on their lands so they can better manage impacts from base operations and support species recovery. However, because large areas of many installations are inaccessible or hazardous, with UXO presenting a special hazard, access by inventorying groups is often restricted or denied.

To address this problem, researchers working on the SERDP-funded project **Acoustic Monitoring of TES in Inaccessible Areas (CS-1185)** have successfully developed and implemented new acoustic systems and software to monitor two breeding songbird species over large areas of Fort Hood (TX), including live-fire and artillery impact areas. Fort Hood hosts the largest breeding populations of golden-cheeked warbler (GCWA) and black-capped vireo (BCVI) (Figure II-12) under a single management authority. Both species are federally listed as endangered.

Figure II-12. The Black-Capped Vireo (*Vireo atricapillus*) Is One of Two Endangered Songbird Species Being Studied at Fort Hood, Texas, with New Acoustic Monitoring Methods.

Autonomous digital recording systems and signal processing software were developed to automatically perform a census of the GCWA and BCVI. The autonomous recording units (ARU) can be deployed for weeks or months at a time to monitor sites that are rarely accessible to biologists. Each unit can be programmed to record sounds that later can be scanned by signal processing

software to identify the species of interest. Ground-based ARUs collected more than 10,000 hours of recordings from 50 sites at Fort Hood. These ground-based recordings quantify diurnal and seasonal variation in temporal singing patterns, and may even show that the breeding status of each male can be inferred from its singing patterns.

Another component of this project was the development of a free-drifting balloon system to record aerial acoustics of the GCWA and the BCVI in sites where ground access is prohibited due to the presence of UXO. The balloon system is equipped with a Global Positioning System to track its location and a digital storage module to record signals from a microphone mounted in a trumpet-like horn. On a typical drift at Fort Hood, approximately 1 percent of the base area can be surveyed by one balloon.

The ground-based and aerial acoustic recording systems have been designed to track other acoustically active species and can be used by the DoD to support the development of effective management plans for threatened and endangered species on other military installations.

This project was recognized and awarded the FY 2003 SERDP Conservation Project of the Year Award at the *Partners in Environmental Technology Symposium and Workshop* held December 2-4, 2003.

Cultural Resource Management

The DoD administers approximately 25 million acres of public land containing some of the nation's most significant historic and prehistoric cultural resources. By law, federal lands must be surveyed and all archaeological sites assessed for eligibility on the National Register of Historic Places (NRHP) or in support of the Native American Graves Protection and Repatriation Act (NAGPRA). Traditional field methods (i.e., surface survey and excavation) used to discover artifacts and architectural elements are time-consuming, expensive, and unreliable. Three SERDP-funded projects are addressing these limitations by developing and modifying advanced methodologies to more accurately and efficiently detect archaeological sites, thereby decreasing the reliance on traditional costly and sometimes arbitrary excavations.

Under the direction of the NASA-Jet Propulsion Laboratory, the SERDP project **Detection and Identification of Archaeological Sites and Features Using Radar Data (CS-1260)** is establishing protocols for the use of Synthetic Aperture Radar (SAR) deployed from aircraft to locate and classify archaeological sites. Multiple radar bands and polarizations employed by aerial SAR are transmitted and received horizontally or vertically, and interact differently with features on the earth's surface (Figure II-13). Because of its variety of archaeological sites, San Clemente Island, located off the coast of Southern California, has served as the test site for this technology. During the first year of the project, images generated from flights over San Clemente Island were input to a Geographic Information System (GIS) that contained detailed environmental information and the precise locations of archaeological sites. In FY 2003, as part of the post-processing phase, radar bands and polarizations were systematically tested to determine their ability to detect the locations of archaeological sites on San Clemente Island. Results indicated that the topographic SAR Digital Elevation Models

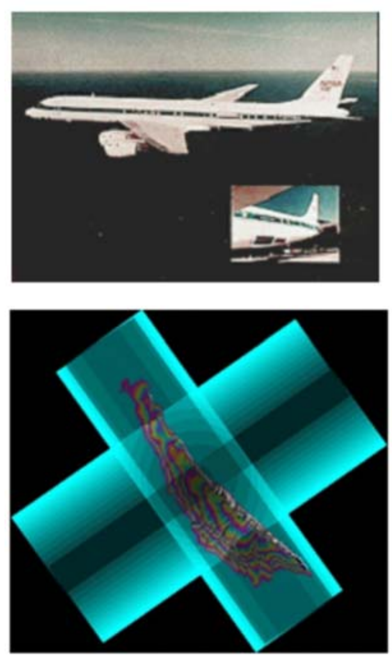

Figure II-13. AIRSAR Radar Coverage of San Clemente Island, California.

(DEM) were highly accurate, allowing precise registration of the radar images to other information layers in the GIS data base. New image processing and post-processing procedures for aerial SAR data produced useful images for the inventory and evaluation of small scale resources. Images have been improved to reduce speckle and enhance backscatter to better highlight archaeological sites. This information supports a predictive model that can be used to determine site and feature signatures. The protocols developed will help to locate sites on DoD lands that are both the most archaeologically significant and the most problematic from a management standpoint.

The SERDP-funded project **Developing an Efficient and Cost-Effective Ground-Penetrating Radar (GPR) Field Methodology for Subsurface Exploration and Mapping of Cultural Resources on Public Lands (CS-1261)** has collected GPR data from two test sites located in Washington and Illinois (Figure II-14). Both sites have buried archaeological features at known depths and orientations that can be used for comparison to GPR maps and other images. The project's goal is to identify the methods that are best suited for locating and mapping buried cultural remains. During FY 2003, the research team conducted laboratory analyses of soil samples collected from each site to determine clay content and type, water saturation, and electrical and magnetic properties. Data indicated that water content most strongly impacts electrical properties that influence radar transmission and reflectance in the ground. As such, it appears to be the most crucial factor in the success of a GPR survey for archaeological mapping. The team also discovered that while the dielectric permeabilities of both clay and quartz sand are nearly identical when dry, they change dramatically with varying water content.

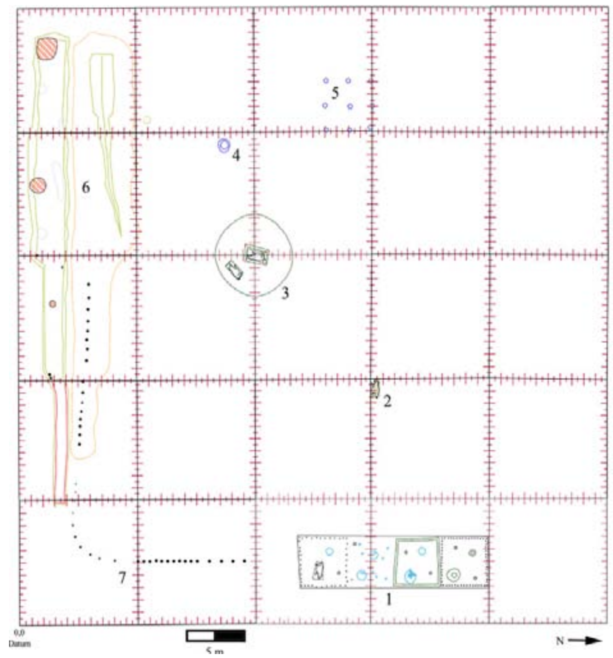

Figure II-14. Controlled Archaeological Test Site – Urbana-Champaign, Illinois.

1. Four Contiguous House Floors
2. Long Pig Burial
3. Burial Mound
4. Roasting Pit
5. House Foundation Piers
6. Ditch and Embankment
7. Palisade

Survey techniques and methodologies applied to the test sites were analyzed and revealed that data collected during the winter (i.e., frozen ground conditions) produced superior spatial correlation with the known features as compared to data collected during other seasons. Tests also indicated that high frequency antennas collecting reflection data in very closely spaced transects provide the best subsurface resolution to detect archeological features.

Data collection and processing steps are currently being synthesized into a field and laboratory GPR protocol that will allow cultural resource managers to predict expected field conditions and make appropriate adjustments that will result in more accurate and efficient detection and mapping of buried cultural remains at DoD facilities. This innovative approach will reduce the reliance on costly and time-consuming traditional archeological excavations. The GPR technology developed in this project will be assessed as part of a suite of detection methods developed in SERDP project CS-1263.

The SERDP project **New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resources Identification and Evaluation (CS-1263)** is investigating the use of a suite of sensors to determine which combinations, data fusion techniques, and analytical approaches most accurately identify archaeological sites on DoD lands. During FY 2002 and FY 2003, geophysical data from magnetometry, magnetic susceptibility, electrical resistivity/conductivity, ground penetrating radar, terrestrial and aircraft thermal infrared, and satellite-based high resolution multispectral imagery were collected at Fort Benning in

Georgia, Fort Bliss in Texas, Fort Riley in Kansas (Figure II-15), and the DOE Savannah River Site in South Carolina. These test sites were chosen based on their range of environments and archaeological resources. All geophysical data have been preprocessed, and preliminary data fusion methods are being used to apply a range of pattern/structure recognition approaches. Anomalies detected in the data fusion and analysis phase will be tested in the field using traditional excavation techniques to quantify prediction accuracy. The multi-sensor surveys permit the detection of archaeological features across large sites, improving the reliability of site assessments.

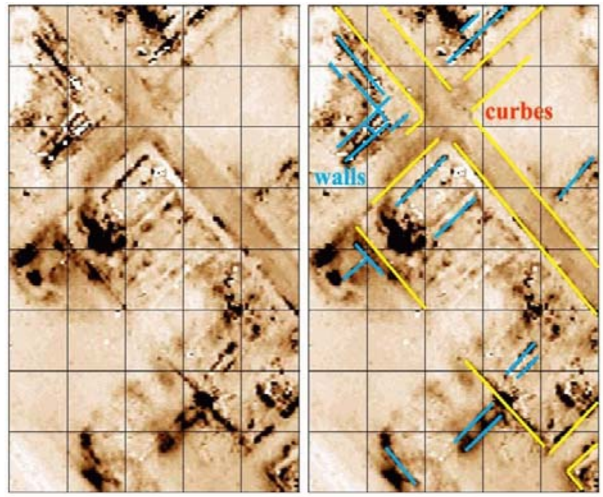

Figure II-15. Magnetic Susceptibility of an Archaeological Site at Fort Riley, Kansas.

Collectively, the results of these three projects will provide advanced tools and technologies to more efficiently and cost-effectively identify and evaluate cultural resources at DoD facilities.

Ecosystem Processes

As part of the effort to ensure sustainable management of military ranges, the military services have expressed the need for a better understanding of ecological processes and trends on military lands, the ecological relationship of military lands to their surrounding lands, and the interactions between mission activities and ecological processes. In response, SERDP established the **SERDP Ecosystem Management Project (SEMP) (CS-1114)** to pursue ecosystem research relevant to DoD ecosystem management concerns. Fort Benning in Georgia volunteered to be the host installation. There are 66 state and federal threatened, endangered, and special concern animal and plant species known to occur on Fort Benning, and several unique and valuable natural communities. Five research teams were selected, with three examining ecological indicators and two examining threshold disturbance. In addition, an Ecological Characterization and Monitoring Initiative (ECMI) team works to characterize the long-term spatial and temporal dynamics of key ecosystem properties and processes (Figure II-16).

Figure II-16. SEMP Research Team Members Seining Upatoi Creek, Georgia.

Ecological indicators can be used to assess the condition of the environment, to provide an early warning signal of changes in the environment, and/or to diagnose the cause of an environmental problem. Ideally, a suite of indicators should represent key information about structure, function, and composition of the ecological system. Recent indicator reports from the Heinz Center, the National Research Council, and the EPA illustrate that many gaps exist in information about indicators. Furthermore, the indicator work that has been completed has largely been at the national, rather than regional, level.

As a component of the SEMP effort, a team from Oak Ridge National Laboratory is integrating ecological indicators from the five research teams. The purpose of the integration is to focus the results of research and monitoring programs on complementing and extending current environmental management at Fort Benning. The proposed set of eight indicators will be screened for their ability to integrate across ecological resources

and to address management needs. The integration screen involves five steps, three of which were initiated in FY 2003. The final result will be a set of ecological indicators and land-use categories for Fort Benning that can be applied to other installations in the region that undergo similar land-use and management practices. A second screen will focus on management needs. Information collected as part of an Integrated Planning Database will be considered in evaluating how well current management needs are being met. Results of this effort will be a monitoring and analysis plan, which will include a list of measures, protocols for data collection, and suggested means for analyses. Ultimately, the lessons learned at Fort Benning should provide an example of how to improve environmental monitoring and management at DoD installations.

Pollution Prevention Accomplishments

Green Energetics

Military munitions are an essential part of the defense arsenal. They include not only gun rounds, missile propellants, and explosives, but also pyrotechnic materials such as flares and smokes. An estimated 500 million pounds of energetic materials are produced each year, producing millions of pounds of hazardous wastes. SERDP research has led to innovative techniques and materials that have significantly reduced toxic wastes associated with munitions production.

Pyrotechnics are used in a variety of military applications (Figure II-17). Two such applications are infrared decoy flares and colored signal flares. Many such pyrotechnic flare compositions contain chlorate or ClO_4^- oxidizers. Residual ClO_4^- released to the ground from these devices may potentially migrate to groundwater and require remediation. Other additives in pyrotechnic flares may also contain chlorine compounds, such as hexachlorobenzene (HCB) or polyvinyl chloride (PVC), which are used as chlorine donors for color enhancement in colored signal flares. HCB is a known carcinogen, reproductive toxicant, and a Superfund hazardous substance that is subject to Toxic Release Inventory (TRI) reporting requirements. When these chlorine-containing devices are employed, hydrogen chloride (HCl) is evolved as one of the reaction products. HCl can react with water in air to form hydrochloric acid, an EPA-regulated toxic chemical that poses a hazard to personnel who may be exposed during the use of these items.

Figure II-17. The Army's CH-47 Chinook Helicopter Employs Counter Measure Pyrotechnic Flares.

In a SERDP project entitled **Elimination of Chlorine Containing Oxidizers from Pyrotechnic Flare Compositions (PP-1280)**, a research team from the Naval Surface Warfare Center-Crane Division (NSWC-Crane) initially sought to investigate the feasibility of reformulating a variety of pyrotechnic compositions to reduce or eliminate chlorine-containing ingredients. However, with the growing regulations placed on ClO_4^- contamination in groundwater, the scope of the project was modified to include not only reducing, but eliminating the use of ClO_4^- as an oxidizer in colored signal flare compositions. In addition to the contamination caused by ClO_4^- oxidizers, the project will continue to avoid, or at least minimize, other environmentally objectionable flare combustion products. The project has formulated three alternative green flare type compositions at laboratory scale and two alternative red flare type compositions that contain nitrate oxidizers instead of the objectionable potassium ClO_4^- oxidizers.

Elimination of Chromium and Cadmium

Preventing the corrosion of metal components on military vehicles, aircraft, and weapon systems is a multi-billion dollar challenge, accounting for 60 percent of annual DoD maintenance costs. Hexavalent chromium, an important component of high-strength steels and sealants, is a known carcinogen. SERDP research has achieved major breakthroughs in the reduction of heavy metals in military waste streams, the development of more efficient application and removal technologies for protective coatings, and the replacement of heavy metals with environmentally benign materials.

Aircraft systems (Figure II-18) require numerous sealants to prevent moisture entry, provide corrosion protection and electrical insulation, and seal fuel tanks. Chromium is the primary corrosion-inhibiting component currently used in sealants. Most of these sealants also contain relatively high levels of volatile organic compound (VOC). Each year, maintenance activities generate a million pounds of waste sealant, with a total disposal cost of $1.5 million. Additionally, depaint/desealing activities in major depot reclamation facilities cost millions of dollars to construct and operate.

Figure II-18. Non-Chromated Sealants Will Achieve Cost Saving on Aircraft such as the F-22.

Through the project, **Replacement of Non-Toxic Sealants for Standard Chromated Sealants (PP-1075)**, drop-in replacement sealants for the chromated corrosion inhibiting sealants were formulated for DoD and DOE applications. The technology was created by formulating a family of salts into a newly developed class of polymer that has greater storage stability and rapid cure. The new material not only has the advantage of eliminating chrome waste, but reduces VOC emissions by 65%, and reduces waste disposal costs by 75% as a result of improved storage stability and improved application properties.

The new sealant is scheduled for release to the market in the fall of 2004. It will be a direct substitution for the chromated sealants and can be transitioned easily via shop trials, test applications and material substitution into national stocks of sealants. The remainder of the project, to be completed by summer 2004, will focus on material qualification and the development of different types and classes of material. The project expects to be able to formulate and test 11 products by the end of the SERDP project. This will cover about 85-90% of the DoD sealant usage. If all 11 products can be transitioned, the project will have eliminated the vast majority of the usage of chromated sealants today. Based on the survey taken prior to this project, this technology should save the DoD $700,000 each year in hazardous waste handling. This project should also save the DoD $110,000 annually from sealants being thrown away, based on the longer shelf life of this technology.

Air Emission Reduction

The painting of military vehicles, ships, and aircraft is required for identification, camouflage, stealth, and corrosion protection (Figure II-19). Every year, the military uses tons of paints and strippers in the maintenance and repair of its numerous platforms. Magnetic radar absorbing material (MagRAM) coatings typically contain VOCs and hazardous air pollutants (HAPs) at levels as high as 600 g/L. In a project entitled **Environmentally Compliant Sprayable Low Observable Coatings that Facilitate Rapid Removal (PP-1181)**, a research team has developed an environmentally-safe, UV-curable, 100 percent reactive liquid coating resin that contains very low VOCs or HAPs. The resin properties allow the coating to be easily

tailored by changing the backbone type and length thus offering significant flexibility in customization to meet platform-specific requirements.

In FY 2003, the coatings formulations were successfully scaled up and the effects of scaling up and batch to batch variations were evaluated. Environmental testing was also completed on the formulations with a VOC content of 1% to 2% by weight. In addition to these environmental benefits, this newly developed RAM coating will provide significant reductions in labor hours required for application. Potential cost savings related to the elimination of VOCs for the DoD are estimated to be between $9 and $30 million annually. This technology has been transitioned for demonstration and validation under ESTCP, and shows promise to significantly reduce VOCs and HAPs in RAM coating applications.

Figure II-19. Radar Absorbing Material (RAM) Coatings Are Used on B-2 Bombers.

Reduction of Hazardous Materials/Solid Waste

The DoD has numerous high performance weapon platforms that require stringent monitoring of the structural integrity of the platforms based on their low tolerance for corrosion and/or cracks. The need to inspect the substrates of these platforms for corrosion, fatigue cracks and other operationally induced damage is very time consuming and costly, often requiring the removal and subsequent replacement of the coating system, as well as the handling and disposal of the hazardous wastes associated with these materials and processes. The paint, stripping, and repainting process generates significant and costly pollutant streams such as VOCs and HAPs. With environmental regulations limiting the emissions of VOCs and HAPs, the DoD has identified removal and reapplication of coatings as major contributors to the emissions problems at DoD facilities. Developing realistic and practical nondestructive inspection technologies for "inspection- through-paint" are considered to be means by which the DoD can extend the life of coatings systems, extend the life of aging weapons systems, meet the increasingly stringent environmental requirements, and increase operational capability with limited assets.

The objective of the SERDP-funded research project **Non-Destructive Testing of Corrosion Under Coatings (PP-1137)** was to develop a nondestructive evaluation (NDE) technique to detect the presence of corrosion and other structural defects with high fidelity under organic coatings in order to reduce the amount of painting and depainting normally performed. Four principal techniques investigated were: spectral nondestructive evaluation (SNDE), wide area spectral imaging (WASI), electrochemical impedance spectroscopy (EIS), and a scanning probe in a conducting gas (SPG).

The results of evaluations of the above techniques indicate that they can be used to detect quantities of corrosion under most conventional coating systems (see Figure II-20). This advanced inspection technology now makes possible the practical use of extended-life topcoat systems, which have the potential to protect aircraft structures for up to 10 years instead of the current five year cycle. Annual cost savings for the DoD are projected at $40 million per year, and four times this amount may be saved in the commercial sector. This technique has been transitioned for demonstration and validation under ESTCP, and shows promise to significantly reduce painting/depainting operations.

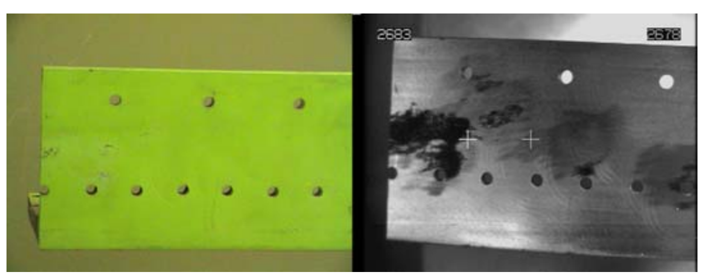

Figure II-20. Application of Infrared Reflectance Technology to the Aircraft Part Coated with Green Primer (left) Revealed Corrosion Underlying the Primer Surface (right).

This project was recognized and awarded the FY 2003 SERDP Pollution Prevention Project of the Year Award at the *Partners in Environmental Technology Symposium and Workshop* held December 2-4, 2003.

UXO Accomplishments

UXO Test Sites for Technology Evaluation

To support the transfer and restoration of contaminated DoD land, advancements are necessary in technology that can detect UXO and discriminate it from harmless ordnance fragments and other nonordnance items. These technologies will also require testing to characterize their performance. To that end, SERDP has funded the establishment of standardized test sites under project **Standardized UXO Technology Demonstration Sites (UX-1300)** to provide a diversity of geology, climate, terrain, and weather, as well as a diversity of buried UXO and clutter. Testing at these sites will be used to fully evaluate UXO characterization technologies, compare the performance of different systems, and compare their performance in different environments, all on consistently constructed sites with common measurement protocols.

This multi-agency project, spearheaded by the U.S. Army Environmental Center, is providing a screening matrix of UXO technology system performance, a series of standardized site protocols, a standardized repository of buried targets and a variety of technology transfer materials. Two sites at Aberdeen Proving Ground (APG), MD and Yuma Proving Ground (YPG), AZ are currently open for technology testing and demonstration. Efforts in FY 2003 culminated in the opening of the YPG site in February of 2003, while multiple vendors actively used the APG site.

Each UXO test site includes a calibration grid, a blind grid, and an open-field scenario. A recently established site at APG is depicted in Figure II-21. The calibration grid allows demonstrators to test their systems with complete access to truth data for a variety of known buried ordnance targets and clutter objects. In the blind grid, the demonstrators are provided the location of each opportunity, but the contents, either ordnance, clutter, or nothing, will be unknown. The blind grid allows for UXO sensor characterization in the absence of uncertainties due to navigation and site coverage. The open-field scenarios test the performance of technologies in multi-acre sites with ordnance and clutter buried at unknown locations to evaluate sensors, sensor platforms, navigation systems, and data processing techniques simultaneously. The open fields present special challenges, including wooded areas, mogul/crater areas, adjacent power lines, steep terrain, and extreme desert environments at YPG.

Figure II-21. SERDP Developed Standard UXO Test Sites to Evaluate UXO Technology Performance for a Variety of Targets and Terrain Scenarios (APG site pictured).

The standardized procedures and performance metrics developed as part of this project will help to ensure that UXO sensor technologies are readily comparable. Results from the test sites will be readily available to local project managers for determining appropriate and effective systems suitable for specific environmental conditions. Protocols developed under the project will assist field managers in developing site-specific geophysical prove-outs with comparable metrics. Data gathered in the process of characterizing

and testing sensors and systems will support future research and development efforts and will hasten the development of more efficient remediation operations.

This project was recognized and awarded the FY 2003 SERDP UXO Project of the Year Award at the *Partners in Environmental Technology Symposium and Workshop* held December 2-4, 2003.

Advanced Sensors for UXO Detection and Discrimination

SERDP-funded efforts in FY 2003 sought to improve the detection and classification of UXO through development of enhanced electromagnetic induction (EMI) sensor systems. Two teams from Lawrence Berkeley Laboratory (LBL) and Johns Hopkins University Applied Physics Laboratory (APL) made significant progress in this area.

The LBL team under **Detection and Classification of Buried Metallic Objects (UX-1225)** is developing an active electromagnetic system that can extract the measurements for the best possible estimates of the location, size, shape and metal content of a buried metallic object in the presence of an interfering response from the ground and/or non-UXO metallic objects. Since its initiation as an FY 2000 SEED New Start, this project has sought to design an optimum system which provides the best detection of UXO with the lowest field survey cost. To achieve this goal, the project is performing basic research to develop a systematic approach for the design and fabrication of an optimum active EM system based on the methodology employed in the minerals exploration industry to search for metallic ore bodies.

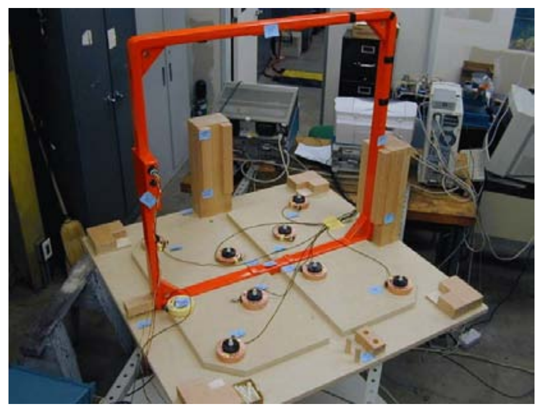

Figure II-22. Photo of the Prototype System.

In FY 2003, the LBL team assembled a bench prototype EM system (see Figure II-22). The preliminary design was assembled to confirm modeling results and to serve as a starting point for an optimized system. A powerful simulator was utilized to optimize the transmitter-receiver configuration. Another simulator was developed to analyze the role of bandwidth and noise in determining the spectral response of the principal dipole moments. The simulators and field measurements of ambient noise enabled researchers to determine the requirements for an optimum system. Laboratory tests confirmed that a complex target can be detected and located. Results also indicate that target size and physical aspect ratio can also be established for enhanced discrimination.

Through SERDP project **Three-Dimensional Steerable Magnetic Field Antenna Sensor System for Metal Target Classification (UX-1314)**, APL is developing a prototype EMI sensor system that can measure the multiple components of a metal object's magnetic polarizability tensor for target classification. To accomplish this objective, a sensor with a time-domain, three-dimensional (3D) steerable magnetic field antenna is under development. The 3D antenna will be modeled, designed, and fabricated to excite the metal object with directionally varying magnetic field vectors without the need to move the antenna spatially over the object. Figure II-23 shows a block diagram of the 3DSMF sensor system concept.

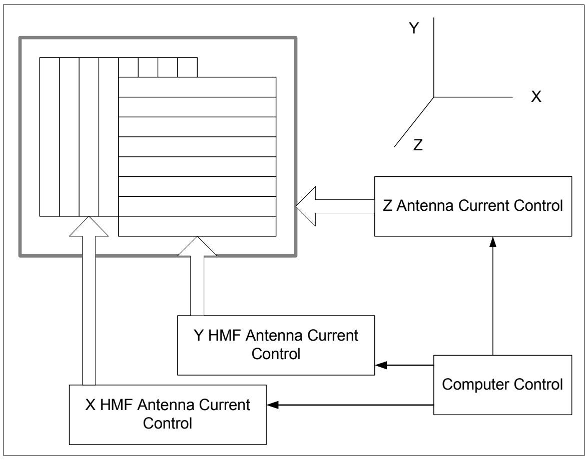

Figure II-23. Block Diagram of 3D Sensor System.

Accomplishments in FY 2003 focused on refining the concept of the sensor system. This included extending existing EMI modeling codes to simulate the 3D sensor system, conducting an antenna optimization study for the 3D transmitter array and conducting an optimization study for a receiver array, developing the mechanical designs for the 3D antenna array and performing system component and integration testing. The sensor system electronic development has been successful. Work completed on other APL projects was leveraged to advance the state-of-the-art in EMI data collection via wireless web-based data acquisition. The development of receiver electronics module has reduced the time it takes to collect data with the sensor system.

Signal Processing for Improved UXO Detection and Discrimination

Figure II-24. Ordnance, Scrap, and Other Metal Items.

Military training exercises and weapons testing spanning many decades have resulted in UXO contamination across significant areas of land. Technologies are required to adequately characterize sites with UXO. The most important metrics are high detection rates and low false alarm rates (i.e., the frequency of declaring a UXO object present when none is there). Until recently, detection algorithms for processing sensor data could not distinguish between buried UXO and clutter even in the most benign conditions, leading to increased false alarms. Recent advances have produced moderate discrimination capabilities in favorable conditions, where high quality sensor data can be acquired and where anomalies are well separated in space and are amenable to signal processing techniques. UXO is often found in densely contaminated areas where it is co-mingled with extensive surface and subsurface clutter composed of metal objects yielding overlapping signatures (Figure II-24). Over the last several years, modern geophysical techniques have merged sophisticated sensors, underlying physical models and statistical signal processing algorithms, to approach these more difficult sites.

The goal of project **Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites (UX-1281)** is to improve signal-processing approaches in highly contaminated regions with signatures of multiple anomalies that often overlap. To achieve this objective, a research team from Duke University is developing new physics-based signal-processing approaches that are applicable to co-existing responses from UXO and clutter items in a sensor signal. The goal of this research is improved discrimination and the use of new measures to identify scenarios where UXO and clutter density is too high for reliable classification.

In FY 2003, the Duke University project team leveraged and extended the multi-level fast-multipole (MLFMA) phenomenological models, developed for EMI and magnetometers under the completed SERDP-funded project **Statistical Signal Processing with Physics-Based Models: Multi-Sensor UXO Detection and Identification (UX-1123)**. The goal of this project is to incorporate interaction effects so that the linearity of the response from multiple proximate objects could be studied in detail. These models will allow for quantification of the performance of UXO sensors as a function of object density. The algorithms that are being developed will provide the ability to separate the signatures associated with different subsurface

objects from a composite signature measured by a sensor. Accurate separation of such signatures will permit remediation of sites that cannot be considered using conventional techniques. The team observed that a single-dipole model provided a good fit for the individual signatures predicted by the model, but a linear combination of the individual signatures did not fit the data that was predicted including the interaction effects. The additional variability that is introduced into the signatures as a result of this nonlinearity was quantified to place bounds on eventual performance. Researchers then used models to generate a more substantial database on which to test the separation algorithms.

An assessment of the simple prescreener, to determine if multiple objects are present for both the GEM-3 and EM61 sensor systems, was also completed in FY 2003. The prescreener was found to be more effective for the GEM-3 as a result of more information. However, in some cases, it is fairly effective for the EM61. Additionally, the research team validated the utility of independent components analysis (ICA) for signature separation, and investigated its behavior on both simulated and experimental data. The amount of variability that is added to the separated signatures as a result of the separation process was quantified, and was shown to be negligible. The signal processing research will result in performance bounds that allow assessment of sensor performance as a function of site parameters.

Quantifying UXO Variability for Target Discrimination

UXO discrimination algorithms have generally relied on characteristic attributes that are consistent across all examples of an ordnance type and that can be used to distinguish the UXO from clutter. In reality, UXO of a given type exhibit differences due to deterioration over time, design and construction of the UXO, or varying degrees of damage due to impact (Figure II-25). This variability can limit the performance of discrimination algorithms. Understanding and quantifying this variability can assist with optimizing the discrimination schemes. The objective of this project is to characterize and quantify the inherent variability in the EMI response of UXO objects and to understand the implications of these results for discrimination.

Figure II-25. These 60 mm Mortar Rounds Show Significant Variability, Complicating the Task of Discriminating Them from Clutter or Natural Items.

Quantification of UXO Variability for Target Discrimination (UX-1313) is investigating discrimination between UXO and clutter by applying decision rules to target-specific parameters derived from site survey data. Within the dipole model framework, these parameters are the EMI response vectors associated with each principal axis of the target, and the decision rules are regions in parameter space. Measurement and modeling errors as well as inherent variability among the UXO themselves cause derived parameters to smear and form a cloud in parameter space. This research will reveal and quantify the distribution that is attributable to inherent UXO variability. Work in FY 2003 focused on development of processing tools and data collection. During the year, a number of site visits were completed where time and frequency domain data were collected on targets at three orientations using the GEM3 and EM-63 instruments. Applicable locations for data collection were determined based on the variability and condition of the UXO available at each site. Test objects (metal spheres, wire loops, and ferrite cylinders) were compared to analytic solutions to establish accurate correction factors for the sensors. Magnetometer data will also be collected in the first part of the next year through additional site visits and will be compared with predictions from models developed under a previously funded SERDP effort. The results of this effort are being compiled for use in related SERDP research on signal processing development.

III. PROGRAM DESCRIPTION

General

The planning and management of individual projects are fundamental to SERDP's success in technology research and development. This section describes each of the SERDP Thrust Area Programs and how the projects respond to DoD needs and requirements. Topics include the goals of each Thrust Area, the environmental and operational drivers directing the needs for new and improved technologies, the major areas of R&D within each Thrust Area, and the planned initiatives. Each FY 2003 and FY 2004 project is listed according to subthrust categorization and completion status.

The SERDP Program contains the following five Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and UXO. Each year the Executive Director, with the assistance of the EWG and the SAB, determines the funding balance among the Thrust Areas. Figure III-1 illustrates the distribution of funds to specific Thrust Areas for FY 2003 and FY 2004.

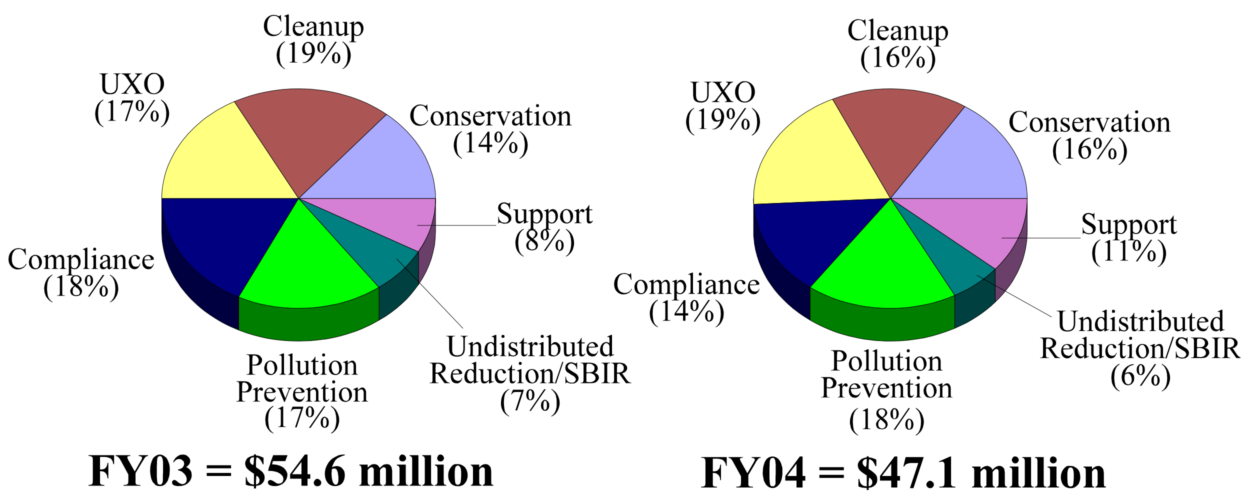

Figure III-1. Distribution of Total SERDP Funding, FY 2003 and FY 2004.

Program Development

SERDP funds environmental research and development through a competitive process in accordance with the established Congressional direction and is further guided by policies provided by the SERDP Council. There are usually two solicitations annually. One is the major, or core, solicitation and provides funding in various amounts for multi-year projects. The other is the SERDP Exploratory Development, or SEED, program designed to provide initial funding for high-risk, high-payoff projects. SEED projects are limited to a one-year time period and a maximum of $100,000 in funding.

SERDP PROJECTS

FY 2003

137	Total projects
43	Completed projects

FY 2004

122	Total projects
28	New Start projects

Because both government and private sector parties may compete for SERDP funds, there are two announcements for each solicitation: (1) a Call For Proposals to the federal sector and (2) a BAA for the private sector. In the FY 2004 federal Calls For Proposals, participating organizations and their laboratories were asked to solicit proposals that responded to the SONs. Each federal organization conducted its own

internal down-select procedure and forwarded its best proposals to SERDP for consideration. The BAAs requested direct submission of proposals in response to the same SONs from non-federal participants in industry, non-profit entities, and academia. Both the core and SEED BAA solicitations appeared in the Commerce Business Daily.

Each year, a peer review panel is used in the core solicitation to assist in the selection of federal and non-federal proposals. Following the peer reviewers' evaluation of technical merit and personnel, those proposals that were recommended by the peer review panels were forwarded to SERDP's multi-agency TTAWGs who were tasked with reviewing both the federal and non-federal submissions of both solicitations for all evaluation criteria. All proposals recommended by the TTAWGs and approved by the Executive Director were briefed to the SERDP SAB prior to recommending their approval to the SERDP Council.

Titles of all projects may be found in the project listings within each Thrust Area description subsection, and summaries of each project are located in Appendices A through E of this report. Detailed descriptions of the FY 2005 SONs can be found in Appendix F.

Cleanup

Introduction

For nearly a century, the military has manufactured, maintained, and repaired thousands of vehicles and hundreds of weapons systems at its 1,700 installations. Following standard industrial practices, millions of pounds of powerful chemicals and solvents were used annually. These weapons systems also consumed billions of gallons of gasoline, diesel, and jet fuel. In addition, the need for realistic training resulted in the annual expenditure of millions of rounds of ammunition, missiles, and pyrotechnics on the training ranges. The result of many decades of military operations was the inadvertent contamination of soil, groundwater, and sediments at many of the installations. The DoD and the DOE, in addressing this contamination, must protect human health and the environment, reduce remediation costs, and provide timely cleanup. Cleanup goals for the DoD are:

- To attend to imminent threats to public health and safety
- To remediate all defense sites having a significant public health risk as quickly as feasible within the constraints of available resources
- To expedite transfer of base realignment and closure (BRAC) sites and formerly used defense sites (FUDS) to future owners

The DoD and DOE have a legal obligation to meet federal, state, and local environmental protection and public health regulations. Due to the large number of DoD and DOE sites and installations, many significant challenges exist and must be addressed. These challenges include chlorinated solvents, especially DNAPLs, as well as recently emerging issues such as ClO_4^-, metals, and energetic compounds (e.g., TNT, RDX, HMX and DNT) in soils and groundwater. Over the past 18 years, the DoD has spent approximately $25 billion for environmental restoration activities. Commensurate R&D funding is necessary to ensure these challenges are met.

Experience with past remediation technology development has demonstrated a significant return on investment. Defense environmental managers require cost-effective and timely remediation capabilities that focus on assessment, characterization, and treatment. Within the Cleanup Technology Thrust Area, the primary environmental concerns are that the DoD:

- Implement timely, effective, and affordable methods for site characterization
- Ensure the use of effective, affordable remediation technologies
- Comply with various federal, state, and local regulations for site remediation

These concerns are addressed by the Cleanup subthrusts and research areas as depicted in Figure III-2.

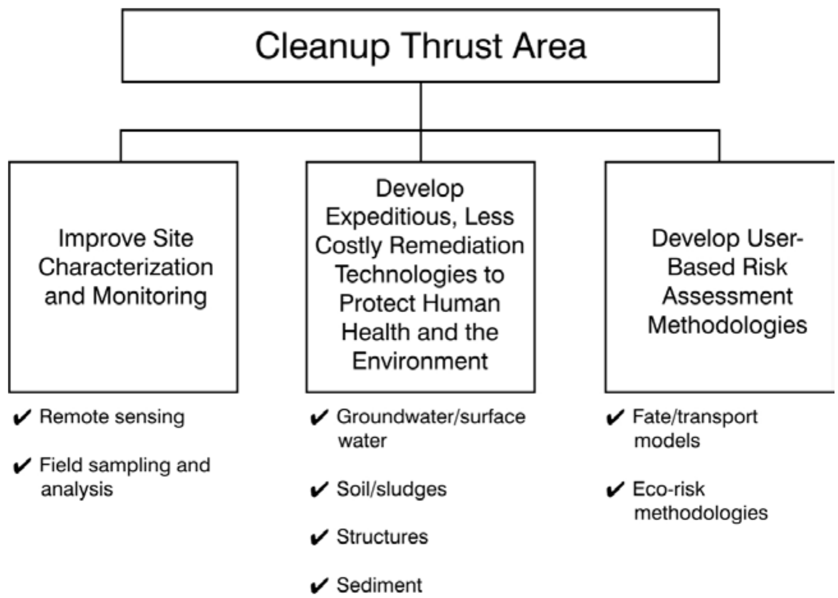

Figure III-2. Cleanup Taxonomy.

While many defense cleanup situations will require that technologies be identified in the near-term, additional research on the scientific fundamentals of contaminant behavior and remediation techniques has the potential to provide the highest return on investment. Congress appropriated funds in FY 2003 specifically to conduct efforts investigating environmental toxicology.

Principal Driving Requirements

The first subthrust area in Cleanup, **Improve Site Characterization and Monitoring**, seeks to develop better site investigation technologies for locating and characterizing wastes. Chlorinated solvents represent a class of contaminants that are detected at more DoD sites than any other contaminant group. Chlorinated solvents, predominantly tetrachloroethene (PCE) and trichloroethene (TCE), have been used in massive quantities over the last four decades. Release of these liquids to the environment accounts for a significant portion of the contaminated sites requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at more than 50 percent of the contaminated DoD sites. There is a comparable degree of contamination at DOE and private industry Superfund sites. Estimated annual costs exceed $500,000 for containing and monitoring a single DNAPL plume. Novel technologies to detect and characterize these plumes will significantly reduce these costs. Also, as more and more contaminated sites enter the active and post remediation stages, the requirement for long-term monitoring has increased. This long-term monitoring can be for process control, performance measurement, or compliance purposes and can last up to 30 years. Current approaches involve sample collection for off-site analysis. New technologies are needed that will measure contaminants in situ/on-site and minimize sampling time and costs. Contaminants of primary concern for DoD include explosives, propellants, heavy metals, and chlorinated solvents.

The second subthrust area in Cleanup, **Develop Expeditious, Less Costly Remediation Technologies to Protect Human Health and the Environment**, focuses on improved remediation of contamination in soils, groundwater, and sediments. Once contaminants reach the groundwater, they often are very mobile and can readily affect off-base receptors. Therefore, this subthrust is directed primarily at developing innovative technologies to address groundwater remediation more effectively. Current groundwater treatment strategies typically employ pump-and-treat technologies, which are expensive to operate and are very slow to achieve lasting cleanup. Major limitations to the use of the conventional pump-and-treat technology relate to difficulties in treating DNAPL source areas. These source areas tend to leach contamination into groundwater down gradient, developing large plumes that may migrate into a drinking water source. The pump and treat technology is generally implemented down gradient of the source area and therefore only treats the contamination that has dissolved from the DNAPL source leading to a long-term remediation scenario. In the area of energetic contamination, DoD is concerned with nitrated compounds that have been identified at munitions training ranges and production facilities. TNT is the primary contaminant at these sites, along with DNT and other nitro substituted explosives (e.g., RDX and HMX). Current approaches used for site remediation typically involve costly excavation of contaminated soils, followed by incineration or composting, and pump and treat for contaminated groundwater. SERDP is conducting research to develop technologies (e.g., phytoremediation) that enable the sustainable use of military testing and training ranges. Because of past DoD and industrial activities, sediments at numerous sites also have some level of impact from anthropogenic compounds (e.g., PAHs and PCBs). A growing body of evidence suggests that sediment removal can at times result in more ecological damage or show no measurable ecological improvement. Because of the large volumes and high costs involved, new technologies to treat contaminated sediments in-place are needed to reduce costs and potential impacts to surrounding areas.

The third subthrust area in Cleanup, **Develop User-Based Risk Assessment Methodologies**, involves identifying and evaluating the risk to human health and ecosystems on DoD installations potentially requiring environmental remediation. These include: (1) distinguishing those sites that pose significant environmental risks from those that pose little risk; (2) prioritizing contaminated sites by the degree of risk posed; (3)quantifying the risks at each site; and (4) developing appropriate remedial actions and cleanup goals. Development of improved techniques for risk assessment, which provide a logical framework for making such decisions, is a DoD priority. Determination of bioavailability is one such technique. The effectiveness of existing risk assessment methods will be expanded by research directed at problems particularly evident at DoD installations (e.g., heavy metals, explosives, and propellants).

Leveraging with other defense science and technology programs and industry, the Cleanup Technology Thrust Area focuses on the following R&D objectives.

- Develop investigation methods and technologies that are capable of locating and characterizing wastes in a timely and cost effective manner with the highest level of quality control.

- Develop innovative, compliant technologies that reduce remediation costs for sites containing explosives, propellants, petroleum hydrocarbons, solvents, heavy metals, and other organic/inorganic contaminants.

- Facilitate transfer of cleanup technologies to field use. This includes, but is not limited to encouraging the use of the National Environmental Technology Test Sites (NETTS). (See Appendix A for NETTS project summaries.)

- Develop cost-effective methods and tools to determine the fate, transport, and effects of significant defense-related contaminants.
- Develop risk-based modeling and simulation methods for hazard assessment and establishing cleanup priorities and scientifically defensible cleanup levels.

- Develop scientifically defensible environmentally acceptable endpoints (EAEs) for DoD chemicals of concern, including chlorinated organics, explosive compounds, and heavy metals, to facilitate risk-based cleanups at DoD sites.

Cleanup Program

For FY 2003, the Cleanup Technology Thrust Area received approximately 19 percent of the SERDP budget. SERDP conducted one solicitation that requested project proposals in FY 2003 for the Cleanup Thrust Area. The solicitation issued four SONs in the areas of DNAPL source zone characterization, diagnostic tools to evaluate remediation performance, sustainability of monitored natural attenuation, and in situ sequestration and engineered reduction of metals bioavailability in soils. Projects resulting from these solicitations are included in this report.

CLEANUP	
FY 2003	
34	Total projects
10	Completed projects
FY 2004	
35	Total projects
11	New Start projects

The following list reflects projects completed in FY 2003 and projects continuing into FY 2004. Also included are titles of projects that will begin in FY 2004. Complete descriptions of all of the projects for FY 2003 and FY 2004 can be found in Appendix A - Cleanup Project Summaries.

Subthrust: *Improve Site Characterization and Monitoring* — Page

Subthrust: *Develop Expeditious, Less Costly Remediation Technology*

FY 2004 New Start Projects

Subthrust: *Develop Risk Assessment Methodologies*

FY 2003 Completed Projects

FY 2004 Continuing Projects

FY 2004 New Start Projects

FY 2005 Cleanup Initiatives

For FY 2005, the SERDP Cleanup Area will solicit proposals primarily in the area of assessing and treating explosive- and propellant-contaminated media in association with testing and training ranges. Other areas of investigation include the development of ecological soil screening levels, exploration of in situ thermal treatment, and research on emergent contaminants.

The first SON explores the **Treatment and Retainment of Explosive - and Propellant-Contaminated Surface Runoff from Training Ranges**. The objective of this SON is to seek applied studies to develop innovative technologies capable of degrading explosive and propellant materials in surface runoff from DoD installations. These technologies should be applicable to large, potentially vegetated areas and should focus on the long-term control of energetic materials through self-sustaining treatment technologies. Research will focus on evaluating synergistic relationships among plants, microorganisms, and physical and chemical properties of the soil, which will allow for optimizing transfer and transformation processes. The contaminants of primary concern are ClO_4^- and RDX, due to their low federal health advisory level and their ability to migrate quickly through the soil matrix, but other explosive and propellant compounds and their breakdown products will also be considered. Results from this research will aid in developing long-term energetic management strategies to minimize or eliminate the potential for energetic contaminants migrating off-site in surface runoff.

The second SON is titled **Screening Level Assessment of Explosive and Propellant Contamination in Soil and Groundwater**. The objective of this SON is to develop innovative, rapid screening technologies to detect and delineate areas with soil or groundwater containing energetic contaminants including explosive compounds (e.g., RDX, HMX, TNT, DNT), propellants (e.g., ClO_4^-), and their byproducts. These tools will be used in the rapid, initial screening assessment of large DoD testing and training ranges in order to locate and delineate potential zones of soil or groundwater contamination that require more detailed follow-on characterization. Successful screening technologies will enhance DoD's ability to perform cost-effective and rapid assessments of large areas within testing and training ranges.

The next SON, **Eco-SSLs and Wildlife Toxicity Reference Values for Improved Risk Assessment at DoD Sites**, seeks the collection of data to assist in the development of Eco-SSLs for plants, invertebrates, and wildlife. Eco-SSLs are soil concentrations of contaminants which, when not exceeded, will protect terrestrial ecosystems from unacceptable harmful effects due to contaminants. Research producing data will support development of: (1) soil screening levels for: 2,4-dinitrotoluene; 2-amino-4,6-dinitrotoluene; 4-amino-2,6-dinitrotoluene; HMX; and nitroglycerin in plants and soil invertebrates, (2) bioaccumulation factors to estimate contaminant concentrations in forage food to use in wildlife exposure risk models for: 2,4-dinitrotoluene; HMX; nitroglycerin; 2,4,6-trinitrotoluene; and RDX in plants, soil invertebrates, small mammals, amphibians, reptiles, and birds, and (3) ecological toxicity reference values for: 2,4-dinitrotoluene; nitroglycerin; 2,4,6-trinitrotoluene; and RDX in birds, amphibians, and reptiles; and 2-amino-4,6-dinitrotoluene; 4-amino-2,6-dinitrotoluene; and HMX in mammals, birds, amphibians, and reptiles. Results from this work will provide knowledge and tools to allow DoD to cost-effectively characterize and predict environmental risk from contaminants of potential concern in soils.

The fourth SON, **Improved Understanding of In Situ Thermal Treatment**, seeks fundamental or applied studies to improve understanding of the mechanisms of removal and destruction of free phase and residual DNAPLs during in situ thermal treatment, including the reductions in plume loading and plume longevity, and the impact of varying subsurface conditions on overall removal and destruction efficiency during thermal treatment. Results from these efforts will lead to: (1) an improved understanding of the potential of in situ thermal treatment for the removal and destruction of DNAPLs; (2) identification of the limitations associated with thermal treatment and (3) development of improved application and monitoring methodologies. Results from this research should provide a greater understanding thermal treatment and improved methods for applying thermal treatment. This additional knowledge will facilitate the use of more cost-effective and efficient remediation at DoD sites.

The final SON is titled **Remediation of Emergent Contaminants**. Through this SON, SERDP plans to fund fundamental or applied studies to develop remedial alternatives for several emergent contaminants. Specific objectives include: (1) Improved fundamental understanding of the mechanisms involved in degradation processes under varying natural and engineered conditions, (2) Elucidation of the impact of co-contaminants on degradation processes, (3) Improved understanding of the behavior of emergent contaminants under typical remedial technologies for co-contaminants, and (4) Development of remedial strategies for emergent chemicals, including consideration of the necessity for treatment train approaches to facilitate treatment of co-contaminants. Specific emergent contaminants of interest include 1,4-dioxane, N-nitrosodimethylamine (NDMA), and 1,2,3-trichloropropane (TCP). Development of a greater understanding of the chemical and microbial processes involved in the degradation of these emergent contaminants will help facilitate the establishment of more cost-effective and efficient remedial action plans that are protective of human health and the environment.

Compliance

Introduction

In the United States, the DoD must comply with federal environmental protection laws, such as the Clean Water Act (CWA), the Clean Air Act and Amendments (CAAA), and the Resource Conservation and Recovery Act (RCRA), as well as state and local regulations. These laws result in specific requirements for the treatment of emissions and disposal of wastes generated during DoD operations, including those generated by vehicles, aircraft, and vessels, as well as from training exercises involving the firing of munitions. At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes (to which the United States subscribes) may restrict or prohibit DoD operations in international waters and MARPOL Special Areas unless vessels meet international environmental statutes. In addition, countries that host DoD facilities are implementing and enforcing compliance with regulations and standards that may restrict or prohibit DoD operations in foreign ports and bases.

Together, these requirements affect numerous defense activities and assets both at home and abroad, including combat testing and training; operational installations; ordnance and weapons manufacturing and disposal; and combat vehicle, ship, and aircraft operations. As a result, DoD is projected to spend approximately $1.7 billion annually for environmental compliance over the next several fiscal years, requiring monitoring and treatment of emissions and wastes generated by military operations and training. New technologies must be developed to reduce this cost and enable the DoD to comply fully with increasingly stringent requirements while fulfilling its mission unencumbered by regulatory fines, restricted access or mobility, or negative public reactions. In addition, full compliance with environmental regulations is a critical step in DoD's initiative to manage its infrastructure and training ranges in a sustainable manner.

Therefore, the mission of the Compliance Technology Thrust Area in SERDP is to research and develop new technologies to:

- Address current and future environmental compliance requirements of the DoD and DOE while maintaining military readiness; and
- Reduce the costs associated with these requirements.

Compliance technologies are not directly related to site restoration but are related to meeting current and future environmental compliance requirements of DoD and DOE. They are applied, for example, to end-of-pipe treatment and/or recycling (i.e., waste that is reused for other than its original purpose), or investigations to assist the development of new regulations which often involve the fate and transport of defense-related air and wastewater discharges. Compliance technologies are increasingly being applied to ensure the sustainable management of military training and testing ranges. Compliance technologies do not include elimination of waste streams through substitution or process modification, which are included in the Pollution Prevention Thrust Area.

The primary concerns in this technology thrust area include deterioration or loss of operational capability and the high costs of regulatory compliance. These primary DoD environmental concerns reflect the need to:

- Better characterize wastes/emissions through improved measuring/monitoring technologies;
- Develop effective treatment/recycling technologies for defense wastes and/or emissions; and
- Develop improved fate and transport prediction capabilities for emissions and/or discharges of specific compounds or contaminants such as explosives residues and metals.

DoD user requirements respond to specific environmental regulations that have been developed under the CAAA, the CWA and amendments, and, for solid and hazardous wastes under the RCRA. Given the compliance requirements that result from these three major laws and their amendments, as well as related standards, SERDP addresses Compliance according to the six major subthrust areas related to affected environmental media shown in Figure III-3.

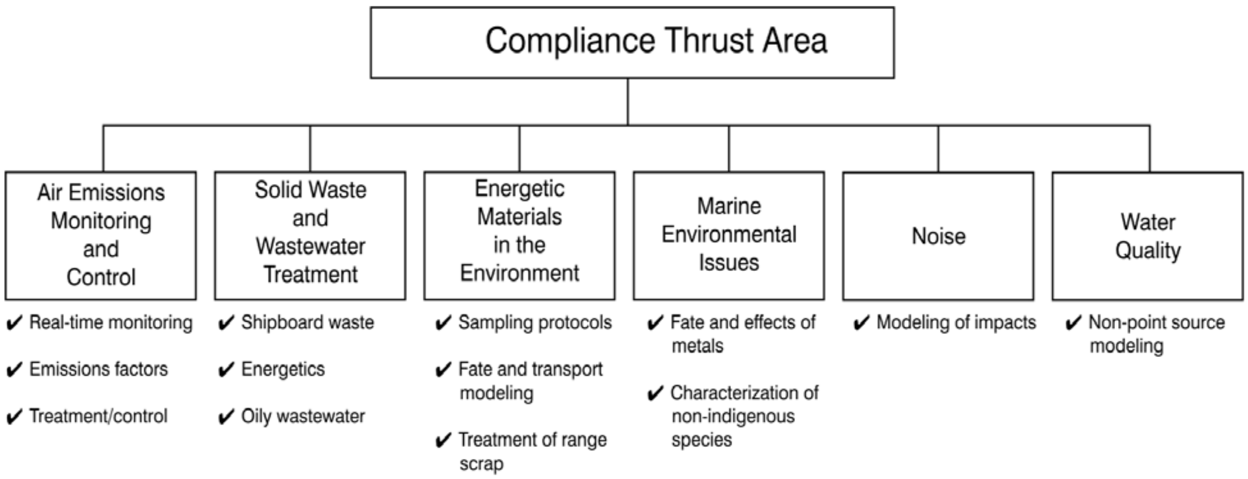

Figure III-3. Compliance Taxonomy.

Principal Driving Requirements

For FY 2003, SERDP responded to requirements resulting from specific regulatory developments via investments in the six Compliance subthrusts. The Air Emissions Monitoring and Control subthrust addresses DoD's need to develop new and effective measuring/monitoring and treatment/control technologies for air emissions resulting from DoD activities. In the course of implementing the CAAA of 1990, a number of local air quality jurisdictions (many facing non-attainment status for one or more priority air pollutants) have imposed local standards that are more stringent than national emissions standards. The employment of military-unique systems such as liquid-fuel rockets, military jet engines, and off-road equipment will require that DoD treat and control emissions of NOx, ultrafine particulate matter (PM), volatile organic compounds (VOC), and HAP at DoD installations. One difficulty associated with monitoring and controlling these emissions is that they frequently are episodic and/or high-volume and low- concentration, such as those from jet engine test cells, and from painting, stripping, and cleaning operations. Existing CAAA regulations continue to test the limits of existing emissions monitoring and control technology, which in some cases does not currently meet portability or detection limit requirements. Anticipated future requirements, such as the expanded National Emission Standards for Hazardous Air Pollutants (NESHAPs), will increase the number of production and maintenance processes that require continuous monitoring and control, thereby creating further technology needs and applications. Additionally, the generation of dust and resultant fugitive dust emissions via military activities is becoming an issue of growing concern due to encroachment around military ranges. Without new technologies to address these challenges, the curtailment of military missions, closing of facilities, and assessment of fines are real possibilities.

The Solid Waste and Wastewater Treatment subthrust addresses DoD's need to meet international environmental regulations limiting the disposal of solid waste and plastics at sea and wastewater streams in general. To address the solid waste need, the Navy must develop compact, efficient equipment for the destruction of solid waste and sludges from waste water onboard DoD vessels. The CWA requirements also prohibit the discharge of untreated sewage (blackwater) by ships in navigable waters. Shipboard greywater

is the product of hotel and commissary-type activities aboard U.S. Navy ships. Common sources of greywater are showers and sinks, and galley and scullery equipment. No greywater holding capacity has been required for U.S. Navy ships with the exception of operations within the Great Lakes. However, with anticipated tightening of global wastewater discharge regulations, DoD must develop technologies that are appropriate to control and treat combined shipboard greywater and blackwater (i.e., non-oily wastewater).

Within the Energetic Materials in the Environment subthrust, research and development is aimed at managing military ranges as a sustainable resource. This subthrust focuses on developing techniques to assess the potential for environmental impacts of residual energetic materials found at military ranges that result from the use of live munitions. The research conducted under this subthrust is intended to contribute to the DoD's capacity to: (1) understand range environmental issues; (2) improve management of these critical resources; (3) assure the long-term viability of these key assets; and (4) facilitate compliance with current and proposed regulations. SERDP research in this subthrust supports the 1996 Defense Science Board (DSB) Report and Environmental Security Plan for testing and training range sustainment. Munition use creates unidentified sources of energetic material in the environment. Characterizing these sources at points of discharge and impact areas has been a key environmental issue in understand the efficiency of the munitions and the possible contamination of the surrounding environments. The EPA is implementing TRI reporting requirements for munitions which will require new and innovative technologies to monitor and characterize emissions of TRI chemicals from munitions discharges and explosions. On a related issue, DoD needs to dispose of an increasing amount of metal scrap material produced by testing and training activities that use munitions and other energetic materials. These scrap materials may contain energetics residues that could pose a hazard to efforts to recycle this metal scrap.

The Marine Environmental Issues subthrust is focused on the scientific fundamentals of the fate and impact of metals from DoD sources in harbors and estuaries, which will be used to develop a scientific basis for future approaches to Cu and Zn regulations. Cu and Zn are two of the most ubiquitous metal contaminants found in many industrial and non-point source effluent, including discharges from DoD facilities, ships, and small craft into the marine environment and from sediments which are disrupted during dredging operations. Studies have shown that Cu and Zn are highly toxic to some marine organisms. DoD needs to provide risk assessments that can identify the DoD sources of Cu and Zn discharging into or present in harbors and/or estuaries and evaluate the risks to marine species from these metals. Examining the fate and impact of these metals has the long-term benefit of providing empirical evidence to support the development of more realistic scientifically-based water quality criteria and standards. SERDP is also conducting research to characterize non-indigenous plant and animal species that may be transported and released from the hulls and ballast water of Navy vessels into estuaries and harbors.

For the Noise subthrust, efforts are required to provide refined acoustic models for improved ability to accurately predict the resulting noise footprint and potential impact of DoD operations. The models would assist environmental specialists in proposing mitigation techniques to site managers and operators. This would be particularly advantageous in regions where the impacts of such operations are dependent on the interaction of environmental conditions. Another objective is to create fully validated models for noise from high performance aircraft and rotary-winged aircraft and other high intensity noise sources such as aircraft weapons to provide a legally defensible characterization of DoD noise impacts.

The Water Quality subthrust efforts address non-point source pollution from DoD activities and the impact to water quality. Section 319 of the CWA amendments established the Non-Point Source Management Program, which requires an assessment of the extent of non-point water quality problems and the development and implementation of best management practices (BMPs) to prevent water runoff from being polluted, and where it is polluted, to reduce the amount that reaches streams, rivers, lakes and estuaries. To comply with these regulations, the DoD needs to identify the sources of non-point source (NPS) pollution, the impact to water quality and provide installation commanders with proactive management plans.

Compliance Program

FY 2003, the Compliance Thrust Area received approximately 18 percent of the total SERDP budget. The annual solicitation issued two SONs in the areas of characterization of off-road diesel vehicle emission of criteria air pollutants, and characterizing and monitoring non-point source runoff from military ranges and identifying their impacts to receiving water bodies.

COMPLIANCE	
FY 2003	
25	Total projects
6	Completed projects
FY 2004	
21	Total projects
2	New Start projects

The following list reflects projects completed in FY 2003 and projects continuing into FY 2004. Also included are titles of projects that begin in FY 2004. Complete descriptions of all of the projects for FY 2003 and FY 2004 may be found on the pages referenced in Appendix B - Compliance Project Summaries.

Subthrust: *Air Emissions Monitoring and Control*

Page

Subthrust: *Solid Waste and Wastewater Treatment*

Subthrust: *Energetic Materials in the Environment*

Subthrust: *Marine Environmental Issues*

Subthrust: *Noise*

FY 2004 New Start Projects

Subthrust: *Water Quality*

FY 2003 Completed Projects

None

FY 2004 Continuing Projects

FY 2004 New Start Projects

None

FY 2005 Compliance Initiatives

FY 2005 Compliance initiatives reflect an emphasis related to (1) characterization and fate of the source term of energetic compounds in aquatic environments, (2) range environmental fate and transport exposure assessment for energetic materials, (3) identification and characterization of natural sources of ClO_4^-, (4) treatment of ClO_4^- in water, and (5) improved methods and monitoring systems for impulse noise.

Managing military ranges as a sustainable resource requires knowledge of the potential impact of energetic materials used in munitions. Developing basic scientific information on the potential sources, transport, and fate of energetic materials that come to reside in the aquatic environments is essential to a more complete assessment of the potential for environmental impact and exposure by those residual energetic materials that might be expected at military ranges as a result of the use of munitions. Testing and training activities can differ markedly in that testing is often intermittent and can involve unique materials, or materials that have not been characterized in detail and that may ultimately fail to become part of an inventory system. Such materials may result in residual energetic materials that could pose a potential for impact to the environment. The potential for environmental fate impacts through the use of munitions in testing and training activities is not presently fully defined or understood. This is of concern in that knowledge of the expected composition, concentration, and distribution of residual energetic materials and their combustion and breakdown products, coupled with an understanding of the ability of these materials to migrate in the environment, are required in order to conduct detailed exposure or risk assessments. In addition to energetic materials, other materials found on testing and training ranges include metals and nonmetallic target materials (e.g., steel reinforced concrete, wooden structures, plastics, asphalt roadways and runways). On a small number of ranges, depleted uranium (DU) has also been used in testing and training activities. To resolve these issues, SERDP has issued a SON for FY05 entitled **Characterization and Fate of the Source Term of Energetic Compounds in Aquatic Environments**. The objective of this SON is to characterize the source term of energetic materials from munitions in aquatic environments and the resulting transport and fate of the energetic constituents. Specific issues to address include assessment of the potential for underwater fate and transport of such residues in freshwater, brackish water and salt water environments that are representative of DoD water training and testing ranges.

Military training and testing range managers require scientific information and management tools to ensure that these ranges can be managed in a sustainable fashion in the near and distant future. A major concern for live fire ranges is the potential transport and offsite exposure of energetic materials that are used by the military services. The energetic materials of concern include: HMX, RDX, TNT, DNT, ClO_4^- and persistent daughter products. As part of an environmental risk assessment, an exposure assessment is performed using source data for each energetic material, the associated environmental fate (degradation), and transport by air and surface water to locations in or near the immediate area. While much work has been conducted to meet these needs, a number of data gaps remain. In addition, screening level modeling tools need to be developed to meet range managers' needs for assessing aquifer vulnerability, identifying contaminant source areas and determining when ranges need to be investigated, cleared and/or remediated or other management actions taken. To fulfill this need, SERDP has issued a SON for FY05 entitled **Range Environmental Fate and Transport Exposure Assessment for Energetic Materials**. The objectives of this SON fall into two main areas: environmental data and development of modeling/management tools. To date, a significant amount of environmental data on Army munitions has been collected; however, data gaps remain regarding Army munitions and less is understood about munitions used solely by the Air Force and Navy. To complete the picture, this SON will: (1) develop the environmental data required to characterize energetics residuals that result from the firing of Navy and Air Force munitions, including both characterizing potential sources and fate and transport; (2) develop the environmental data to characterize potential releases and fate of ClO_4^- as they occur on training and testing ranges; and (3) characterize residuals from gun propellants and characterize leaching rates of contaminants bound in these materials. Work also has progressed in recent years towards developing the fate and transport models required for exposure assessments. However, this work has not fully addressed assessments for energetic materials nor has it fully addressed the screening level tools needed by range managers. This SON will also address the following areas: (1) screening level tools are required to accurately and confidently predict aquifer and/or surface water vulnerability at training ranges based on site activities and site hydrologic/hydrogeologic characteristics; (2) modeling tools are required to link data for residual energetics in surface soils with groundwater data so as to aid in management decisions; and (3) tools that will enable range managers to determine if and to what extent ranges must be characterized, cleared or remediated based on the types of live-fire activities conducted and site-specific soil and climatic and hydrogeologic conditions and/or that can be used to determine the frequency of range clearance required to protect ground water.

ClO_4^- is the soluble anion used by the DoD since the 1940s as a critical component in military combat and training munitions including pyrotechnics, propellants, explosives, mines and rocket/missile fuels. Concerns regarding the presence of ClO_4^- in the environment have grown since 1997, following its detection in the drinking water of more than 15 million people in the western United States. ClO_4^- is highly persistent in the natural environment. ClO_4^- has been found to occur naturally in the environment and is normally associated with certain nitrate deposits. The occurrence of these deposits in areas of California and Chile has raised the question as to the origin of the ClO_4^- in these areas and the possible levels to which treatment may or can be required for potable waters. The extent of these naturally occurring ClO_4^- deposits and the means by which they came into existence are not fully known. At present there is no national environmental standard regulating ClO_4^-. To expand the knowledge base of naturally occurring ClO_4^-, SERDP has issued an SON for FY 2005 entitled **Identification and Characterization of Natural Sources of Perchlorate**. The objectives of this SON are to: (1) identify the biological and/or geochemical processes that can lead to the formation of ClO_4^- under natural environmental conditions; (2) identify the potential mechanisms that can lead to accumulation or concentration of naturally formed ClO_4^- in the environment; and (3) identify soil and climatological conditions that could lead to the formulation and creation of ClO_4^-.

DoD will require cost-effective treatment approaches for the removal of ClO_4^- in drinking water, treatment residuals, and waste waters. These approaches should provide options for meeting any environmental standard that may be required in the future. This information will be used by DoD installations to make decisions when there is a need to provide treatment of ClO_4^- in water. In addition, the information will be used as guidance for the selection of a treatment technology on or off military installations. In addition, these approaches should provide scientifically defensible evidence of the efficacy of ClO_4^- treatment in drinking

water to prevent future liability. To fulfill this need, SERDP has issued an SON for FY 2005 entitled **Treatment of Perchlorate in Water**. The objective of this SON is to: (1) provide new, cost-effective, and innovative treatment technologies and approaches for removal of ClO_4^- from drinking water to 1 ppb or less; and (2) provide new, cost-effective, and innovative treatment technologies and approaches to reduce or eliminate ClO_4^- from residual wastewaters generated by drinking water or other treatment processes. These technologies would be characterized by low capital and operating costs, simple operation, low energy consumption and minimal monitoring and maintenance.

Impulse noise is a short duration event (typically less than one second), of high intensity onset and rapid decay, and often exhibits rapidly changing spectral composition. Impulse noise is characteristically associated with such sources as explosions, impacts, the discharge of large caliber weapons (20mm or greater), and sonic booms. Impulse noise monitoring is an important tool for assessing noise impacts from military training and testing activity. Routine testing and training range operations can generate complaints and damage claims from civilian communities around DoD installations. These claims can result in testing and training restrictions and expenditure of funds for compliant and damage investigation, as well as damage itself. Most military installations were established in rural areas that were remote and isolated from population centers. Over time, this has changed as communities have developed and grown around these military installations. The sum effect has been that installations, once far from public view, are now often in the midst of densely populated areas. Noise is one of the inevitable consequences of military training practices and increasingly is becoming a concern for communities in the vicinity of these military installations. To proactively respond to this potential restriction, SERDP has issued an SON for FY 2005 entitled **Improved Methods and Monitoring Systems for Impulse Noise**. The objective of this SON is to improve methods for the monitoring and analysis of impulse noise. Specific attention is focused on reducing the recording of false-positives, eliminating labor-intensive data analysis, improving diagnostic software, and providing the capability for date/time data queries, etc. This research will develop a cost effective solution to improve installation noise monitoring systems by: (1) reducing false-positive events while maintaining accurate logging of real impulse noise events; (2) providing monitoring data in easily retrievable format, such as Microsoft Excel or Access; and (3) presenting monitoring data in an easy to understand manner which will facilitate public outreach.

Conservation

Introduction

DoD is a major user of land, sea, and air, and manages approximately 25 million acres of land on more than 425 major military installations. It is the third largest federal land management department in the United States. DoD requires continued access to these lands, waterways, and airspace to maintain mission readiness. Land is needed for munitions testing, deployment of weapon systems, and combat training exercises. Marine and estuarine environments are needed to conduct training exercises, test vessels and submarine tracking equipment, evaluate missile weapon systems, and conduct shock trials on new ships. Airspace is needed to train pilots and test fighter planes and air-based weapon systems. The specific landscapes and unique natural features of the land, sea, and air space used by DoD are crucial to maintaining military readiness. Varied training regimens and differing climatic, topographic, hydrologic, and biological settings prepare troops to operate equipment and carry out operational plans under conditions that they may encounter in future conflicts. With a broad geographic distribution (largely domestic but some foreign), DoD lands represent a remarkably diverse collection of ecosystem and habitat types, including forests, grasslands, wetlands, and deserts. DoD's ability to conduct realistic training exercises and to test weapon systems and equipment cannot be ensured without responsible land stewardship and sensible management and conservation practices.

DoD must sustain the ability to train personnel and test weapons while maintaining the natural and cultural resources of the installations upon which it depends. It also must comply with legislation and regulations designed to protect these resources. By better understanding the environments in which they operate, the

Department can improve its resource-use decisions to promote conservation and stewardship, while continuing to fulfill their primary missions. The DoD Conservation goal is to support the military mission by: (1) providing for sustained use of its land, sea, and air resources; (2) protecting valuable natural and cultural resources for future generations; (3) meeting all legal requirements; and (4) promoting compatible multiple uses of those resources.

Furthermore, military facilities face increasing demands as a result of base closures and realignments, new weapon systems and equipment requiring larger training ranges, additional regulatory constraints, and changes in tactics and doctrine. Training intensity on remaining installations will continue to rise, often preventing full recovery of vegetation and animal populations between training exercises. The U.S. Army alone has millions of acres of training and testing lands with significant land repair and maintenance costs. On-site and off-site environmental impacts, wildlife conservation issues, cultural resources concerns, and the need for training realism all dictate that natural resources must be maintained and enhanced on these installations. The tasks of balancing military land uses, complying with resource regulations, and assessing impacts on the sustainability of both the resource base and the military mission are complex and challenging. Activities to alleviate one problem can often exacerbate others. All too often, decision-makers on military installations are faced with making critical land management decisions without the benefit of complete environmental information nor complete knowledge of other, competing objectives and/or land use requirements.

Leveraging with other Defense science and technology programs and similar programs in industry and academia, SERDP focuses on the following Conservation research and development objectives to support DoD's Conservation goals.

- Develop standardized, cost effective methods to inventory, characterize, and monitor natural and cultural resources to help ensure compliance with applicable laws and requirements. Where appropriate, use defense-unique data collection and assessment tools to develop these methods.

- Develop and demonstrate more effective methods and techniques to maximize availability of military lands in support of military missions, with minimal impact to natural and cultural resources in a manner consistent with the Services' mission and federal environmental regulations.

- Develop and demonstrate efficient and effective techniques to conserve and restore natural and cultural resources proactively, particularly threatened and endangered species and the ecosystems on which they depend.

- Develop and demonstrate effective, user-friendly computer-based models to determine the incremental and cumulative impact of military activities on natural and cultural resources, and assess effectiveness of conservation and restoration techniques.

- Develop state-of-the-art techniques to assess and predict the impact of military use on those critical elements of the ecosystem impacting sustainability.

- Develop the needed methods, tools, guidelines, and decision support systems for effectively implementing integrated resource management techniques.

These research and development objectives are addressed and implemented under five related but distinct subthrusts which makes up the Conservation Taxonomy (as depicted in Figure III-4). Current focus areas or critical paths to DoD conservation goals are listed under each subthrust. These focus areas may change from year to year in order for the subthrust to appropriately adapt to new DoD requirements.

Principal Driving Requirements

DoD manages species of concern, and specifically Threatened, Endangered, and At-Risk Species, to comply with the same laws and statutory provisions as all other federal Agencies, including the Endangered Species Act (ESA) of 1973, the Marine Mammal Protection Act of 1972, and the Migratory Bird Treaty Act. In addition, the following legal authorities apply specifically to the management of **Threatened and Endangered Species** on DoD owned or managed lands: "Conservation Programs on Military Installations (Sikes Act)," National Environmental Policy Act, the Fish and Wildlife Coordination Act, and others. The Threatened, Endangered, and At-Risk Species subthrust addresses DoD specific requirements that pertain to those species that are identified as either threatened or endangered (both currently and potentially). It is known that more than 200 installations provide habitat for at least 400 plants and animals that are listed on, or candidates for, the federal endangered species list. This is the highest known density of threatened and endangered species found on any federal lands. Research and development must be responsive and as proactive as possible in meeting all DoD requirements pertaining to these plants and animals.

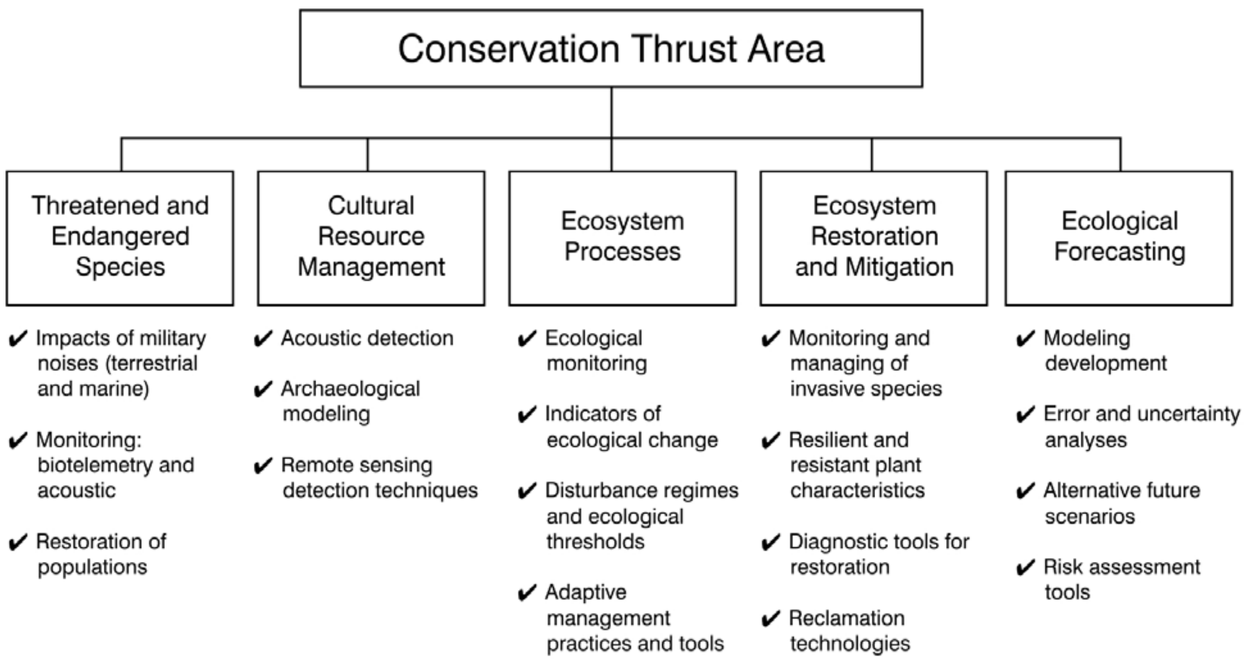

Figure III-4. Conservation Taxonomy.

The research and development focus for the Threatened, Endangered, and At-Risk Species subthrust has included the effects of aircraft overfights on birds of prey, biotelemetry, marine mammal responses to low frequency noise, whale monitoring, training noise impacts on the Red-Cockaded Woodpecker, salmon in the Pacific Northwest, acoustic monitoring of TES in inaccessible areas, acoustic response and detection of marine mammals, and smokes and obscurants impacts to aquatic TES. The challenge for the Threatened, Endangered, and At-Risk Species subthrust will be to integrate the approaches and findings of research and development pertaining to specific species into the context of an ecosystem management approach. DoD recognizes that a species-by-species approach to resource management is potentially inefficient and can lead to contradictory management strategies. DoD has adopted an ecosystem approach to managing its natural resources. This approach considers groups of plant and animal species, instead of focusing on single-species management. It promotes adaptive management, the use of benchmarks and the best available science, and sustainable use for both human and ecological purposes. One way of doing this will be to integrate regional management strategies more effectively by reducing conflicting individual approaches. Working within an eco-regional context can help protect the viability of resident populations and reduce the likelihood of future listing of species under the ESA.

DoD lands contain more than 100,000 archaeological sites, and at least 200 installations have properties that are listed on or eligible for the National Register of Historic Places. Approximately two percent of all the military's buildings and structures are considered historic. Management of cultural resources on the many and varied military installations in the United States is necessitated by respect and by public laws that include, but are not limited to, the National Historic Preservation Act of 1966 as amended; the Archaeological Resources Protection Act of 1979 as amended; and the Native American Graves Protection and Repatriation Act of 1990. The **Cultural Resource Management** subthrust addresses the research and development needs associated with the detection, sampling, and preservation of cultural resources on DoD installations. The R&D focus for this subthrust has included acoustic detection, archaeological modeling, remote sensing detection techniques, development of aerial radar detection protocol, ground-penetrating radar detection, and integration of multi-sensor remote sensing identification techniques. The reduction of cost and increase in efficiency are key drivers for defining the research and development investments in the Cultural Resource Management subthrust.

As part of its stewardship goal, DoD is charged to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic (including marine) ecosystems while supporting human needs, including the DoD mission. All of the DoD services have expressed the need to better understand ecological processes and trends on military lands, the ecological relationship of military lands to their surrounding lands, and the interactions between mission activities and ecological processes. The goal of the **Ecosystem Processes** subthrust is to provide knowledge, tools, and techniques to permit military land managers to evaluate the ecosystems on their installation and to predict the responses to military operations as well as to effectively manage the lands for long term sustainability and use. This subthrust focuses on addressing science and technology requirements for ecosystem management of DoD military installations. The current R&D focus for this subthrust includes the creation of long term monitoring site(s) on DoD lands to observe ecosystem trends over time, identifying ecosystem change indicators, understanding disturbance within the ecosystem resulting from military mission activities and land management practices, development of adaptive management practices and tools based on ecosystem monitoring, development of miniaturized sensors to monitor and determine ecosystem parameters, mapping, monitoring and analysis of coral reefs communities, and investigation of benthic community structure and function using the Benthic Index of Biotic Integrity method. The challenge for the Ecosystem Processes subthrust will be to incorporate the findings/result of ecological monitoring and new understanding of ecosystem processes into the development of practical adaptive management tools for installation resource managers that are transferable across an ecoregion.

Within the DoD, the military services are required to maintain and restore remaining native ecosystems across their natural range of variation, and to ensure long-term sustainability of military training and testing lands and waters in support of the National Defense mission (DoD Instruction 4715.3). The **Ecosystem Restoration and Mitigation** subthrust addresses the research and development needs associated with the

restoration of natural systems and their functions and values, with a goal of sustaining the health, productivity, and biological diversity of ecosystems in concert with the mission of military readiness and environmental compliance requirements. The research and development focus for the Ecosystem Restoration and Mitigation subthrust includes monitoring and managing of invasive species, identification of resilient and resistant plant characteristics, diagnostic tools for restoration, reclamation technologies, and riparian ecosystem management and restoration. In practice, much of DoD's restoration efforts are engineering driven and site specific without much regard to the significance of the functions in which the site(s) serves within the ecosystem or ecoregion. With the increased emphasis on an integrated ecosystem-based approach to management of federal, State, and private lands, ecosystem restoration has emerged as an important area of interest. To be fully realized and implemented, ecosystem restoration requires the integration of the understanding of ecological processes into reclamation technologies and engineering practices. The goal of the Ecosystem Restoration and Mitigation subthrust is to identify research and development opportunities that will facilitate this integration.

Ecosystems provide the background for the DoD to maintain its military readiness. To sustain these ecosystems, decision makers must take into account potentially interactive effects of natural variability and human induced change on ecosystem structure, function and productivity. A key role of science is to provide insights into the potential scale, direction, and nature of that change. SERDP funded research and development in the **Ecological Forecasting** subthrust is aimed at forecasting the ecological response to current and/or expected change using models and other decision-making tools. The current R&D focus for the Ecological Forecasting subthrust includes modeling development, error and uncertainty analyses, alternative future scenarios, and risk assessment tools. A key driver over the next decade for the Ecological Forecasting subthrust will be urban change in areas surrounding DoD installations. Research and development should have a critical contribution to the establishment of a comprehensive understanding of the dynamics of urban change outside DoD installations and how this change will effect the sustainability of military range lands. Decision tools will be instrumental for the development and implementation of installation-community planning policies, procedures and forums, as well as, serving to facilitate daily management decisions on DoD installations.

Conservation Program

For FY 2003, the Conservation Thrust Area received approximately 14 percent of the SERDP budget. SERDP conducted one solicitation that requested proposals in the Conservation Thrust area. The annual solicitation issued three SONs that address specific impacts to aquatic threatened and endangered species, estuarine ecosystem management and restoration, and assessment of benthic communities.

CONSERVATION	
FY 2003	
21	Total projects
5	Completed projects
FY 2004	
18	Total projects
2	New Start projects

The following list reflects projects completed in FY 2003 and projects continuing into FY 2004. Also included are titles of projects that begin in FY 2004. Complete descriptions of all of the projects for FY 2003 and FY 2004 may be found on the pages referenced in Appendix C - Conservation Project Summaries.

Subthrust: *Threatened and Endangered Species* **Page**

FY 2004 Continuing Projects

FY 2004 New Start Projects

Subthrust: *Cultural Resource Management*

FY 2003 Completed Projects

FY 2004 Continuing Projects

FY 2004 New Start Projects

None

Subthrust: *Ecosystem Processes*

FY 2003 Completed Projects

None

FY 2004 Continuing Projects

FY 2004 New Start Projects
None

Subthrust: *Ecosystem Restoration and Mitigation*

FY 2003 Completed Projects

FY 2004 Continuing Projects

FY 2004 New Start Projects
None

Subthrust: *Ecological Forecasting*

FY 2003 Completed Projects
None

FY 2004 Continuing Projects

FY 2004 New Start Projects
None

FY 2005 Conservation Initiatives

The FY 2005 initiatives focus on four out of the five Conservation subthrusts and reflect an emphasis on (1) identification of vectors for transport of non-indigenous species, (2) monitoring of migratory birds on DoD land, (3) development of biogeochemical cycle models for Fort Benning ecosystems, and (4) detection of TES and their habitat.

During war, peace-keeping missions, and regular training activities, it is necessary for troops and their equipment to deploy to regions across the globe. In addition, for military personnel to train as they will need to fight, it is often necessary to transport both troops and vehicles to installations across the country. Each

and every time troops deploy, there is a high likelihood that plant, animal, and potential pathogen "hitch hikers" also tag along. Current inspection and wash facilities do not catch and eliminate all of these unwanted organisms. To address this need, SERDP released an FY 2005 SON entitled **Identification of Vectors for Transport of Non-Indigenous Species by Department of Defense** for the Ecosystem Restoration and Mitigation subthrust area. The objective of this initiative is to develop methods to identify and control the spread of non-native invasive species (NIS) that may be inadvertently transported by DoD vehicles and/or personnel. The identification of significant pathways for NIS transport and subsequent development of more targeted and improved methods for NIS reduction prior to transport will help DoD better comply with Executive Order (EO) 11312 as well as with DoD's stewardship goals. Preventing the introduction and spread of NIS has significant management and cost savings benefit by precluding the potential for future long-term expensive clean up and compliance obligations, including the potential for loss of training lands due to impacts to TES.

DoD natural resource managers need to know what species occur on or migrate into, out of, or through individual installations, what management needs exist for those species, what monitoring techniques and protocols work best for each species, and what percent of a species population exists on military lands. Currently, there is no comprehensive strategy for when and how to monitor migratory birds on military lands. When monitoring is carried out, the resulting information may not provide an accurate answer to relevant management issues. To address these issues, an FY 2005 SON released under the Ecological Forecasting subthrust, entitled **Development of an Advanced Monitoring Strategy for Migratory Birds on Military** will determine the fundamental relationships of various environmental elements that define migratory landbird habitat and routing, and understand how these elements contribute to bird distribution and abundance that can lead to improved monitoring strategies. Efforts proposed under this SON will lead to the coordination and standardization of migratory bird monitoring programs on military lands, and provide the basis for more accurate environmental risk assessments to comply with the Migratory Bird Treaty Act (MBTA) and ESA. Furthermore, it would contribute to the development implementation of improved mitigation procedures to protect migratory bird species without degrading realistic military training, which is imperative to maintain military readiness, and help DoD avoid or minimize conflicts between bird conservation responsibilities and its primary missions.

Nutrient cycles in the ecosystem, including soil carbon content as well as available nitrogen content, can be unique site quality indicator factors and simultaneously can be an important component of an overall land sustainability analysis. Moreover, the factors that are being developed as parts of the SERDP Ecosystem Management Project (SEMP) (i.e., threshold, indicator, productivity, nitrogen cycle, carbon cycle) contribute environmental information for site management decisions. To address nutrient cycling needs, an FY 2005 SON for the Ecosystem Processes subthrust entitled **Developing Terrestrial Biogeochemical Cycle Models for Fort Benning Ecosystems** was released. The objective of this initiative is to develop models for biogeochemical cycles that (1) contribute to an overall understanding of ecosystem dynamics and (2) enable development of nutrient availability thresholds that can assist land managers in determining appropriate land uses and land management approaches for ecosystems associated with Fort Benning, Georgia (on the installation and within the surrounding regions). Of primary concern are the carbon and nitrogen biogeochemical cycles, and their interactions relative to nutrient resource thresholds. The result of this work will provide DoD and regional land managers with tools that will support installation-level management decisions regarding land use, ecosystem restoration and maintenance for sustaining the military mission (i.e., training and testing), and for recovery of TES. At the same time it will support regional ecosystem quality, while providing site-specific, and potentially exportable, information.

Many wildlife species and even the habitats those species occupy can be difficult to observe and study. Specific difficulties related to military lands include, but are not limited to, (a) remote and/or nearly inaccessible location; (b) potentially wide range; (c) sparse and/or low species density; (d) nocturnal or other habits/life history; (e) cryptic and/or similarity of appearance to other species; (f) inaccessibility of dwelling places/habitat; (g) small size; and (h) seasonality. To assist in addressing these issues, an FY 2005 SON entitled **Improved Remote Sensing Technologies for Detection of Threatened and Endangered Species**

and their Habitat is presented and supports initiatives under the TES subthrust. The main objective is to develop new remote sensing technologies to detect high priority TES and their habitats(s) on DoD lands. Of particular interest are those TES that are inaccessible (e.g., in burrows or hidden roosts) during certain life stages or during part of the day/night. It is anticipated that the techniques developed pursuant to this SON will result in reduced costs and/or improved accuracy of the detection of high priority listed species and their habitats. This information will also help military installation managers address their responsibilities under the revised Amendments to the Sikes Act where, under the Integrated Natural Resource Management Plan (INRMP), each installation must facilitate the protection of TES and their habitats.

Pollution Prevention

Introduction

The DoD and DOE have a number of unique functions, such as the development and operation of sophisticated weapons systems, which demand specialized, high-performance materials. Many of these materials are toxic and are targeted for voluntary reduction. The challenge to DoD and DOE is sustainability, which translates to finding new high-performance materials that are not toxic and/or to determine innovative ways to control the use of toxic chemicals in order to reduce releases and off-site transfers.

The SERDP Pollution Prevention Technology Thrust Area focuses on reducing or eliminating the generation of pollution from DoD activities. The application of pollution prevention technologies will influence positively the other DoD environmental Thrust Areas by encouraging the use of innovative technologies and practices such as recycle, recovery and reuse, reducing pollutants to be managed at the source, and promoting the sustainable use of natural resources.

As defined under the Pollution Prevention Act of 1990, pollution prevention means “source reduction” and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials. Source reduction is defined as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal.

The Pollution Prevention Thrust Area, at the recommendation of the SERDP Scientific Advisory Board, is adopting a proactive approach to provide solutions to the highest priority defense-related environmental problems. The Pollution Prevention Thrust Area, in addition to addressing near-term multi-service DoD problems, also will address more forward looking, high-risk, long- term projects to achieve the goals that will be set forth by future regulations. For example, the development of the next generation of environmentally advantaged DoD systems is key to meeting potential future regulations. This will be done by designing tools to alert planners to potential environmental issues. SERDP will work closely with military planners, Service research organizations, and the ODUSD(I&E) to identify long-term needs for the DoD.

The Pollution Prevention TTAWG continues to emphasize a program shift toward the more global, Tri-Service issues and on developing seed technologies to address emerging regulatory issues. The TTAWG has envisioned SERDP's role as a facilitator in communication and collaboration to enhance technology transfer and to leverage Service and SERDP resources. This will be achieved through increased interaction with the National Defense Center for Environmental Excellence (NDCEE), the National Center for Manufacturing Sciences (NCMS), and participation in the Joint Group on Pollution Prevention (JG-PP).

The primary DoD environmental concerns in Pollution Prevention are:

- identifying alternatives for hazardous and toxic chemicals and materials;
- reducing the use of hazardous and toxic chemicals and materials;
- reducing the volume and toxicity of wastes and pollutants through source reduction;
- improving the efficiencies of mechanical and chemical systems;
- incorporating environmental ramifications as key evaluation considerations in major system design and acquisition;
- considering the life-cycle effects of materials and systems; and
- evaluating the sustainable use of resources.

These DoD Pollution Prevention needs are addressed by the five major sub-thrust areas of Air Emissions, Halon Replacements, Elimination of Chromium and Cadmium, Green Energetic Materials, and Reduction of Hazardous Materials and Solid Waste, and are further delineated in Figure III-5.

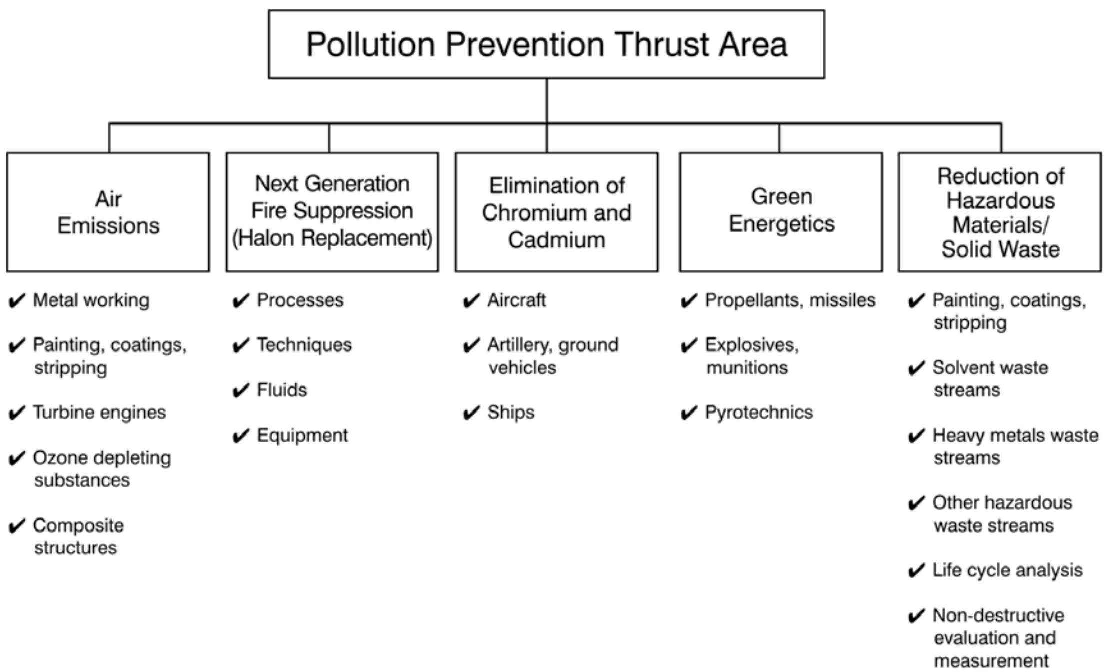

Figure III-5. Pollution Prevention Taxonomy.

Future SERDP Pollution Prevention projects will be selected based on the following general metrics: (1) expected payoff (i.e., potential cost avoidance); (2) magnitude of the environmental problem that the technology will address; (3) clearly identifiable potential environmental benefits and impacts on the defense establishment, regardless of whether the project addresses current, near-, mid-, or long-term needs; and (4) leveraged funding from Services/Agencies applied to the project.

Principal Driving Requirements

Congress has enacted several laws that are primary drivers for DoD and DOE to green up their manufacturing, production, and repair operations. Just a few include the Clean Air Act, CWA, Pollution Prevention Act, RCRA, Solid Waste Disposal Act, and Toxic Substances Control Act. The White House has also directed the federal Government through a series of EOs to take actions to prevent pollution. In 1999, EO 13123 "Greening the Government Through Efficient Energy Management," and EO 13134 "Bio Based Products and Bioenergy," were signed by the President. In April 2000, EO 13148 "Greening the Government Through Leadership in Environmental Management" directed DoD and other federal agencies to establish new pollution reduction goals. In response, DoD has implemented three new reduction goals: (1) reducing the Toxic Release Inventory by 40% by 2006; (2) reducing the use of 15 targeted chemicals by 2006 by focusing on replacement of common processes and chemicals; and (3) eliminating the purchase of all Class I OSDs by December 31, 2010.

In the **Air Emissions** subthrust, SERDP is funding a wide array of projects addressing reduction or elimination of VOCs in adhesives, lubricants, and sealants, pollutants in composites and low observable coating, and emissions from engines. The 1990 CAAA, the RCRA, and state and local regulations restrict the emission and disposal of these hazardous materials. Ozone depleting substances (ODS) are being phased out of production under national policy and international (Montreal) protocol. DoD directives require significant reductions in hazardous wastes and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of hazardous, non-hazardous, and special wastes that are expensive to manage and dispose. The Military Services as well as SERDP are addressing the upcoming 10-year Surface Coating NESHAP, through research and development.

The replacement of Halon, an ODS , in fire fighting technologies is a major focus of research in the **Next Generation Fire Suppression** subthrust. Halon 1301 (CF3Br) has long been the choice for fire extinguishment in most weapon systems and mission-critical facilities. However, due to its high ozone-depletion potential, halon 1301 was banned from production as of January 1, 1994, under the Copenhagen Amendments to the Montreal Protocol on Substances that Deplete the Ozone Layer. The objective of this subthrust is to develop and demonstrate environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. The benefits of this subthrust will be demonstrated alternatives to halon 1301 usage that will enable DoD weapon system managers to make prudent decisions in removing their dependence on a key zone-depleting substance in a manner that offers the least fiscal and operation barriers to implementation.

The research in the **Elimination of Chromium and Cadmium** subthrust focuses primarily on finding environmentally friendly sealants and coatings as well as better application methods. Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. The DoD and DOE have committed to replace chromate-based metal finishing in present and next generation systems. It is well known that chromates pose a significant toxic hazard to human health and their use has been subject to strict regulation. It is the desire of regulating agencies, manufacturers and the user community to replace chromate corrosion protection technologies. Chromate corrosion protection technologies will only be replaced when environmentally friendly corrosion protection technologies achieve acceptable levels of performance. Significant, strategic investments in chromate elimination research have been made, and these efforts have contributed significantly to our understanding of corrosion protection by chromates.

The **Green Energetics** subthrust assesses the current environmental issues associated with energetic materials and energetic material-containing systems to identify major areas of concern and investigate innovative technologies for the synthesis of environmentally friendly ammunition, energetics, propellants, smokes, and flares. Medium caliber ammunition (20mm to 60mm in size) environmental problems are being addressed in a systematic manner, through an umbrella program, advised by a Technical Advisory Committee (TAC). Based on TAC recommendations, key areas of interest include a green priority matrix identifying specific contaminants and quantities. The matrix assigned a high, medium, or low priority for the various contaminants and calibers involved. Elimination or replacement of lead and toxic heavy metals was deemed highest priority based on the pollution contribution quantity and toxicity. Primary sources of these materials in medium caliber ammunition are the primer and detonator in the fuze. The development of environmentally benign alternatives will reduce or eliminate range contamination; mitigate the long term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at the various 20mm to 60mm ammunition manufacturing facilities. It will also result in reduced safety risks and reductions in prolonged exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling and disposal of toxic materials during production, test, and operational use of medium caliber munitions. Economic benefits include reduced ammunition, training and production site cleanup costs. Significant cost avoidance could be realized through elimination of approximately 10 tons of lead required to support production of medium caliber training ammunition over the next six years.

During this decade, an increased emphasis has been placed on pollution prevention to reduce environmental impacts associated with DoD weapon systems acquisition. The DoD Pollution Prevention Strategy of August 11, 1994, established a goal to identify and develop environmental life cycle cost estimating tools that inject pollution prevention and other environmental concerns into acquisition decisions. Development and application of modeling and simulation tools to identify and test technical solutions that reduce reliance on toxic materials and processes are required. Within the **Reduction of Hazardous Materials/Solid Waste** subthrust, SERDP is funding numerous, wide-ranging projects addressing alternatives to hazardous and toxics chemicals and processes such as cleaning agents, anti-freeze, corrosion protectors, and coatings as well as the reduction of solid waste associate with the packaging of military rations. Virtually all DoD maintenance and repair activities for weapon system components involve the use of toxic or hazardous substances. In 1998, EO 13101 directed "Greening the Government Through Waste Prevention, Recycling, and federal Acquisition." It encouraged the expansion of markets for recovered materials, environmentally preferable products, (including biobased products), and established the organizational structure to ensure full accountability. Under this EO, federal agencies must establish specific goals for (1) waste prevention and recycling or solid waste diversion, (2) affirmative procurement of products that are made with recovered materials, and (3) procurement of environmentally preferable products and services for which a pilot project has been successfully completed. Agencies will annually evaluate their progress toward attaining these goals.

Additionally, SERDP continues to use topical studies and workshops as tools to identify DoD/DOE user needs, to better understand the existing state-of-the-art technology in these areas, and to identify environmentally driven requirements. In addition to fostering technology transfer, this information is used to help focus the SERDP program on the highest priority issues and to avoid duplication of effort. SERDP's Pollution Prevention program has taken a systems approach to continue to work on the next generation of concepts/materials through the development of SONs derived from DoD user requirements. These workshops provided an opportunity for communication between the Requirements, User Communities and SERDP. These communication lines will enhance future efforts to provide guidance and devote resources to the pressing environmental issues that continue to face the DoD.

Leveraging with other DoD, DOE, and EPA science and technology programs and industry, the Pollution Prevention subthrust areas focus also on the following research and development objectives.

- Alternative materials and processes to replace defense use of hazardous heavy metals (e.g., lead, nickel) and metallic compounds and hazardous air pollutants.

- Techniques to regenerate, recycle, and re-use defense unique toxic chemicals and materials.
- Cost-effective, environmentally preferable packaging and recycling approaches to reduce generation of solid waste from defense-related operations.
- Predictive models (which include environmental life cycle costing) to aid in the development of environmentally sound weapon systems and platforms during concept development, design, test and evaluation, maintenance (logistics support documentation), and decommissioning.

Pollution Prevention Program

For FY 2003, Pollution Prevention received approximately 17 percent of the SERDP budget. SERDP conducted two solicitations that requested proposals for funding in FY 2003 in the Pollution Prevention Thrust Area. Early in FY03, a supplemental solicitation was released issuing three SONs in the areas of propellant compositions, stab detonators, and lithium-free batteries for medium caliber munitions. The annual solicitation issued six SONs in the areas of chromium-free coatings, metal parts cleaning for electroplating, liquid spray paint components, alternatives to nickel electroplating, radar absorbing material coatings removal, green synthesis of energetics, and chromate-free welding rods.

POLLUTION PREVENTION	
FY 2003	
28	Total projects
9	Completed projects
FY 2004	
23	Total projects
4	New Start projects

The following list reflects projects completed in FY 2003 and projects continuing into FY 2004. Also included are titles of projects that begin in FY 2004. Complete descriptions of all of the projects for FY 2003 and FY 2004 may be found on the pages referenced in Appendix D - Pollution Prevention Project Summaries.

Subthrust: *Air Emissions*

Subthrust: *Next Generation Fire Suppression*

FY 2004 New Start Projects

None

Subthrust: *Elimination of Chromium and Cadmium*

FY 2003 Completed Projects

FY 2004 Continuing Projects

FY 2004 New Start Projects

Subthrust: *Green Energetics*

FY 2003 Completed Projects

FY 2004 Continuing Projects

Subthrust: *Reduction of Hazardous Materials/Solid Waste*

FY 2005 Pollution Prevention Initiatives

SERDP is proposing three new Pollution Prevention initiatives through the issuance of three core SONs. The focus of the FY 2005 program is development of (1) alternatives to ammonium ClO_4^- in projectile formulations, (2) environmentally benign cadmium plating alternatives, and (3) non-ozone depleting solvents for precision cleaning.

The objective of the first FY 2005 Pollution Prevention SON, **HAP-Free Solvents for DoD Hand Wipe Cleaning Applications**, is to develop a zero HAP, low VOC solvent or family of solvents that are suitable for hand wipe cleaning operations in DoD maintenance facilities. It is anticipated that many of the most commonly used HAP solvents will be banned in the near future and that the mission capability of systems under acquisition could be impacted by the availability of low VOC/zero HAPs cleaning solvents. The DoD has a coordinated plan to address the requirement for qualified replacements for NESHAP regulated solvents that includes short-, mid- and long-term goals. The goal of this solicitation is to address long term objectives for the development of alternative cleaning materials produced from environmentally benign chemistries and not to focus on short-term process alternatives.

The objective of a second FY 2005 Pollution Prevention SON, **Alternatives for Perchlorate in Incendiary Mix and Projectilve Formulations for Projectiles**, is to develop environmentally benign, ClO_4^--free incendiary and pyrotechnic mix technologies for projectiles. The focus of this SON is to eliminate potential future ClO_4^- soil, surface water and groundwater contamination from training and testing of munitions as well as from production and disposal of these munitions. ClO_4^- are used as an oxidizing component in some of the incendiary mix formulations and flash compositions used in projectiles. These formulations are used as markers to produce an incandescent flash (and smoke) to mark the impact point, as ignition sources for flammable liquids, and as igniters to initiate explosive trains on impact. Proposed technologies must be capable of meeting or exceeding current DoD-required safety and performance criteria which include, but are not limited to toxicity, stability, sensitivity, ignitability, hygroscopicity, candle power, and burn time.

Human health and ecological considerations during the lifecycle of the incendiary mix and during ingredient manufacture must be addressed. As a secondary objective, the proposed alternative must still be visually scoreable but should reduce the propensity for hot spots and brush fires on training ranges.

The objective of the third FY 2005 Pollution Prevention SON, **Environmentally Benign Medium Caliber Gun Barrels**, is to develop environmentally benign (hexavalent chromium [Cr]-free, low-VOC, low-HAP) techniques, materials, and processes to protect medium caliber (20mm to 40mm) gun barrel bores from in-service wear and erosion. Proposals are being sought that shall include testing to measure the performance capabilities of the resulting coatings and/or liners. These tests should include, as a minimum: (1) erosion studies in realistic configurations with actual propellant gases, (2) thermal cycling from room to maximum in-bore temperatures followed by a water quench, and (3) adhesion of the coating/liner materials. Relatively mature approaches should also include test firing studies to evaluate: (1) gun bore erosion, (2) firing accuracy, and (3) rifling durability issues. System performance needs to meet or exceed that of the current systems. Additional technical elements that must be addressed in this SON include, but are not limited to, cleaning or surface preparation treatments and corrosion protection if appropriate.

UXO

Introduction

SERDP established the UXO Thrust Area because UXO has been identified by the Services as the highest priority environmental need. UXO presents a major challenge to DoD in its effort to remediate closed, transferred, and transferring (CTT) ranges, such as sites designated for BRAC and FUDS. It also is a challenge for active military installations seeking to manage their test and training ranges as sustainable assets. In the United States alone, current estimates indicate that more than 50 million acres of land with varying terrain, vegetation, and topography are potentially contaminated with UXO. Using current technologies, cost estimates for identifying and disposing of UXO in the U.S. range from $10's of billions to over $100 billion. New technologies capable of detecting UXO with high detection rates and low false alarm rates are required to reduce drastically the cost of site characterization and cleanup.

Until recently, “mag and flag” was the standard procedure for site characterization for UXO. In a “mag and flag” operation, a magnetometer or electromagnetic induction sensor is used and anomalies are identified by real-time human interpretation of sensor response, which is usually presented as an audible signal set at some operator-determined threshold. “Mag and flag” has generally produced detection rates that are unacceptably low and the number of nonhazardous items detected that must be investigated far outnumber real ordnance. Technical capability has developed beyond “mag & flag” for open terrain; digital sensors paired with modern GPS navigation collect data systematically, providing a map of sensor responses. Such systems have led to improvements in detection and reduction in false alarms at simple sites. However, advances are still needed to improve detection and discrimination under a variety of operational conditions, to develop sampling techniques for wide-area surveys, to improve vehicle and man-portable production surveys, and to interrogate individual items for explosive hazard.

The DoD is focused on protecting human health and the environment, reducing remediation costs, and providing timely cleanup of UXO-contaminated sites. Technology objectives for the DoD are:

- develop tools to perform initial assessment of sites that require large area survey;
- develop tools to provide detailed site characterization;
- develop tools for cost-effective, cued object discrimination;

- develop standards and protocols for navigation, geolocation, and data acquisition and processing;
- develop tools to aid in the cost-effective removal and disposal of UXO; and
- develop decision tools.

These technology objectives are addressed by the major subthrust areas depicted and further defined in Figure III-6.

UXO cleanup, at the current rate of progress, will require decades to complete. Ongoing defense UXO characterization and remediation projects must rely on technologies that can be identified in the near-term and additional research in this area has the potential to provide the highest return on investment decreasing both overall cost and cleanup time. The Department requested and Congress appropriated an additional substantial increment of funds for FY 2002 specifically to conduct UXO-related research. Following a competitive selection process, projects in response to this appropriation were initiated late in FY 2002 and are still continuing. This increase in UXO-related research funding has established a firm foundation for SERDP to continue to be the leader in DoD for UXO-related R&D.

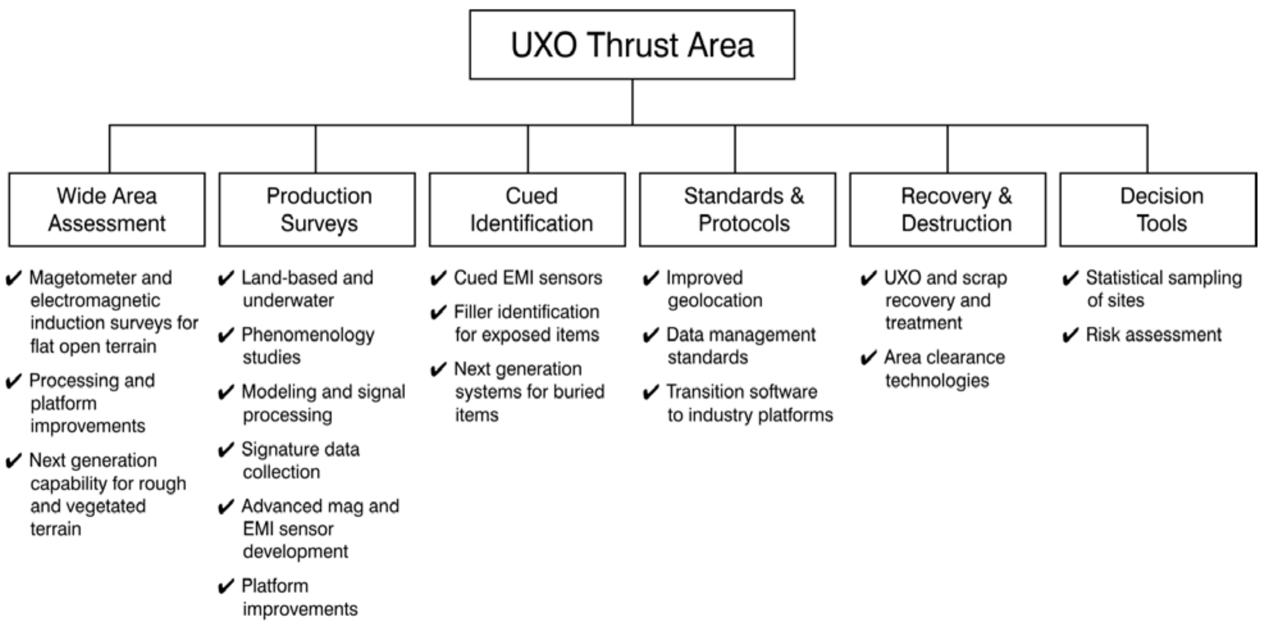

Figure III-6. UXO Taxonomy.

Principal Driving Requirements

SERDP's UXO thrust area supports the Department's efforts to advance the state of the technologies used in conducting UXO investigations. SERDP investments in UXO have two principal objectives. First, these efforts seek to improve the overall effectiveness of response activities in the areas of worker safety, overall protection of human health and the environment, and long-term effectiveness. Second, these efforts are seeking solutions that may assist in reducing the overall program cost associated with the DoD munitions response program. With the wide variations in site size and complexity, terrain, vegetation, geology, the type of ordnance used at the site, the reasonably anticipated future land use, and other factors, in support of these objectives DoD is pursuing UXO technology advancement on a broad front, seeking improvements that will be useful across a broad spectrum of sites.

To provide focus to the program, the Department has established six objectives specific to UXO technology development. These objectives do not represent single endpoints of the technology development process, rather they describe classes of technologies required to meet specific operational needs. Consequently, SERDP has organized its UXO research program (see Figure III-6. UXO Taxonomy) into subthrust areas that mimic the same technology objectives.

The first subthrust area in UXO, **Wide Area Assessment**, involves the rapid identification of areas that require detailed characterization. These systems are primarily airborne platforms that allow rapid coverage of large sites. Unit costs (e.g., dollars per acre covered) for wide area surveys are much lower than costs for detailed characterization. Because of their relatively high speed and the height of the sensor above the ground, these systems are currently capable only of detecting large objects or dense clusters of small objects. With the exception of operations in flat, open areas, these systems are not able to provide the high degree of detection efficiency and geo-location accuracy found with man-ported or vehicle mounted systems. Future developmental activities are focused on extending the use of these systems to a wide variety of terrain and improving their ability to detect smaller ordnance.

The second subthrust area, **Production Surveys**, is the most heavily invested area at present. Production surveys currently use single or multi-sensor arrays to collect the data used to detect and locate UXO both on land and underwater. Following collection, this data is analyzed using computer modeling and simulation software. Significant progress has been made in improving detection capabilities, however, discrimination between UXO and innocuous materials with similar sensor signatures has not seen the same level of improvement. New sensor concepts are in development, which when coupled with similar efforts to improve the post-collection processing systems, should lead to greater improvement in detection and discrimination capabilities. Advanced towed, man-portable and hand-held systems that improve the current detection and discrimination capabilities and that are deployable across all sites are being developed.

The next subthrust area, **Cued Identification**, supports the definitive identification of UXO located during production ground surveys. Cued identification is a key element in discriminating between UXO and innocuous materials with similar sensor signatures, and is a critical feature of efforts to reduce the inefficiencies caused by poor discrimination. Systems to discriminate ordnance shapes from other metal, and to discriminate explosive-filled items from inert practice rounds are being developed.

The fourth subthrust area, **Standards and Protocols**, involves technologies focused on the collection, management, and evaluation of geophysical data. It includes, the establishment of standardized test facilities and protocols, which enable the evaluation and comparison of detection systems under reproducible conditions. These facilities also aid in generating valuable data to support further development and optimization of these systems. SERDP maintains an awareness of ongoing related activities, in both the ESTCP program and elsewhere, and considers it an area for future exploitation given the availability of funding.

The fifth subthrust area, **Recovery and Destruction**, is focused on developing systems that will improve the safety and efficiency of UXO recovery and destruction activities. Developing tools for mass clearance of highly contaminated areas, removal and destruction of UXO in all environments, and treatment of residues are of primary interest. While not presently funding research in this area, SERDP maintains an awareness of ongoing related activities and considers it an area for future exploitation given the availability of funding.

The final subthrust area, **Decision Tools**, is focused on developing methods to guide and evaluate actions throughout the UXO response process. Developing statistical assessment tools, quality control tools and hazard assessment are of primary interests. At most sites, UXO is concentrated in specific areas and effective footprint reduction is needed so that resources can be focused in the area of highest contamination. Supporting footprint reduction decisions, protocols developed with SERDP funding will fulfill the need for a statistically defensible procedure to assess sites through sub-sampling.

Leveraging with other defense science and technology programs and industry, the UXO Technology Thrust Area focuses on a subset of the R&D objectives that are listed under the Cleanup Thrust Area. Namely, those objectives that apply to the UXO problem are as follows.

- Develop investigation methods and technologies that are capable of locating and characterizing UXO in a timely, cost effective, and quality manner.
- Develop innovative, compliant technologies that reduce remediation costs for sites containing UXO.
- Facilitate transfer of those UXO-related technologies to field use. This includes, but is not limited to encouraging the use of the Standardized UXO Test Sites developed under SERDP and ESTCP funding.
- Develop risk-based modeling and simulation methods for hazard assessment and establishing remediation priorities and scientifically defensible "no further action" decision points for UXO-contaminated land.

UXO Program

For FY 2003, the UXO Technology Thrust Area received approximately 17 percent of the SERDP budget. In FY 2003, SERDP conducted only a SEED solicitation that requested small innovative project proposals in the UXO Thrust Area following the large number of projects resulting from the FY 2002 supplemental solicitation. SERDP issued a solicitation with three SONs for FY 2004 focused on advanced approaches for UXO detection and discrimination, identification of filler material in recovered UXO, and site characterization and remediation technologies for UXO contaminated underwater sites.

UXO	
FY 2003	
29	Total projects
13	Completed projects
FY 2004	
25	Total projects
9	New Start projects

The following list reflects projects completed in FY 2003, and projects continuing into FY 2004. Also included are titles of projects that begin in FY 2004. Complete descriptions of all of the projects for FY 2003 and FY 2004 may be found in Appendix E - UXO Project Summaries.

Subthrust: *Wide Area Assessment* **Page**

<u>FY 2003 Completed Projects</u>
None

FY 2004 Continuing Projects

FY 2004 New Start Projects

None

Subthrust: *Production Surveys*

FY 2003 Completed Projects

FY 2004 Continuing Projects

FY 2004 New Start Projects

Subthrust: *Cued Identification*

FY 2003 Completed Projects

None

FY 2004 Continuing Projects

FY 2004 New Start Projects

Subthrust: *Standards and Protocols*

FY 2003 Completed Projects

FY 2004 Continuing Projects

None

FY 2004 New Start Projects

None

Subthrust: *Recovery and Destruction*

FY 2003 Completed Projects

None

FY 2004 Continuing Projects

None

FY 2004 New Start Projects

None

Subthrust: *Decision Tools*

FY 2003 Completed Projects

FY 2004 Continuing Projects

None

FY 2004 New Start Projects

None

FY 2005 UXO Initiatives

SERDP is seeking to develop technologies to support characterization and/or remediation actions for unexploded ordnance found on underwater sites. To this end, in FY 2005, the SERDP UXO Thrust area will solicit proposals for research under the following SON: **Site Characterization and Remediation Technologies for Unexploded Ordnance (UXO)-Contaminated Underwater Sites**. To direct remediation efforts appropriately and to clean underwater UXO areas reliably, SERDP intends to develop techniques that provide reliable target detection and discrimination, and remediation tools that can cost effectively and safely remove or dispose of UXO. The primary interest of the program is to address UXO that is accessible to people and presents a potential hazard. As such, technologies appropriate for the shallow water (15-60 feet) and very shallow water (<15 feet) environments will be favored.

Another UXO-related proposed area of new research is entitled, **Dual Mode Navigation for Portable Platforms**. The goal of this SON is to develop dual-mode navigation tools to support collection of geophysical data using hand-held or man-portable sensors. The navigation system should be capable of operating in rough, vegetated terrain, where handheld sensors will be required and where satellite access (DGPS coverage) is often limited. The first (coarse) mode would be used for logging of anomalies in search mode and would permit efficient reacquisition. The minimum performance requirement is approximately +/- 0.3 m rms absolute error, and the desired objective +/- 0.1 m, for X,Y coordinates (i.e. in the horizontal plane). No Z or vertical navigational information is required for the coarse mode. A second (fine) mode would support the collection of high-density data in the vicinity of the anomaly that would support the requirements of discrimination algorithms. This mode would require highly accurate relative positioning to create local maps of single anomalies. The minimum performance requirement for the fine mode is +/- 0.10 m rms relative error, and the desired objective +/- 0.01 m in the X,Y, and Z coordinates. The two modes will not necessarily use the same base technology, but should be selectable with easy operator switching between modes. A system suitable in size, weight and power requirements for a hand-held or cart-mounted platform and compatible with geophysical sensors is required.

The intended objective of the UXO-related proposed area of new research entitled **Magnetometer or Electromagnetic Induction Sensors and Processing** is to develop novel sensors and signal processing techniques applicable to the diverse detection and discrimination problems of UXO-contaminated sites. Capabilities are needed for a wide variety of site conditions, particularly those with difficult geology, terrain and vegetation, and complex ordnance and clutter distributions. The goals of this SON are to develop next-generation electromagnetic geophysical sensors to collect vector data, either in the active or passive mode, as well as the development of signal processing techniques to treat the resulting complex data streams. Such sensors have the potential to increase standoff distance or allow comprehensive search with less than 100% terrain coverage.

The SON entitled, **Systems Integration Study**, requests proposals to support system level studies to specify characteristics of potential future optimal UXO detection/discrimination systems. Proposed efforts may

address hand-held, man-portable, vehicular or airborne platforms. Recent and on-going projects under SERDP and other funding have explored multiple aspects of sensor and platform development, signal processing, and phenomenology. Integrating these multiple aspects to produce an ideal detection and discrimination system will require trade-offs of many inter-related variables that will constrain performance at the systems level. These include but may not be limited to platform stability, power consumption, navigation, data rates, processing strategies, sensor receivers and transmitters and many others.

The final solicitation for FY 2005 is for one year efforts under the SERDP SEED program. The goal of the SON entitled **Innovative Approaches to Unexploded Ordnance (UXO) Cleanup**, is to develop proof of principle for new sensors, explore new discrimination techniques, develop new removal or disposal technologies, or to explore technologies that support such efforts through improvements in navigation, geo-location or ground, water, or aerial vehicle technologies. Advances are needed in all aspects of the detection, discrimination and disposal of UXO in both land and water environments. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in a variety of environments, using a variety of supporting vehicle and navigation technologies. Algorithms are needed that can exploit data from current state-of-the-art sensors and advanced sensors that are now becoming available. Once hazardous and non-hazardous items are distinguished, the hazardous items must be removed and/or disposed of in a cost-effective manner. The proposed work should, if successful, lead to a continued development effort, which ultimately could result in the fielding of new sensors, implementation of algorithms, testing of removal or disposal techniques, or in improving operation of the approaches used to date though improved navigation, geo-location or vehicle performance. There is interest in any aspect of improving UXO clean-up procedures in both land and water environments.

Detailed descriptions of all of the FY 2005 SERDP SONs may be found in Appendix F.

APPENDIX A
Cleanup Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Naval Base Ventura County, Port Hueneme, CA; CU-863

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ernest Lory, Naval Facilities Engineering Service Center, Port Hueneme, CA

FY 2004 FUNDS: $600K

DESCRIPTION: The objective of the Naval Base Ventura County (NBVC) National Environmental Technology Test Sites (NETTS) National Test Location (NTL) at Port Hueneme, CA, is to support demonstration of technologies for characterizing and remediating soil, sediments, and groundwater contaminated with fuel hydrocarbons, waste oil, and fuel additives such as methyl tert butyl ether (MTBE). It provides test sites to investigate both ex situ technologies for treatment of soils and in situ technologies for groundwater. The Test Location Manager (TLM) at NBVC, Port Hueneme provides programmatic, infrastructure and technical support to researchers for characterization and remediation demonstrations. Programmatic support includes integration of the following: (1) Quality Assurance/Quality Control (QA/QC) procedures, (2) test protocol guidance, (3) demonstration reporting format, and (4) environmental setting, cost and performance data retrieval guidance. Infrastructure and its management (operation and maintenance) include: (1) monitoring wells, (2) in-line sensor network, (3) ex situ treatment facility with hazardous material handling capability, (4) utilities, and (5) contaminated soil, sediments and groundwater resources. Technical support will include: (1) characterizing and monitoring contaminants, (2) processing permits, (3) supporting stakeholder involvement, and (4) transferring technologies.

BENEFIT: The NTL for fuel hydrocarbon and waste oil provides well characterized test locations, controlled field conditions for comparative evaluations of technologies, uniform evaluation criteria for demonstrations, reporting of results and technology transfer, and cost savings through amortization of infrastructure and management.

ACCOMPLISHMENTS: In FY 2003, the Port Hueneme NETTS hosted the Interstate Technology Regulatory Council (ITRC) MTBE meeting, prepared the MTBE air sparging Technical Regulatory Guidance section, and conducted two NETTS Advisory Committee meetings during which the Port Hueneme and Dover committees were joined. NETTS obtained permission to install a characterization test cell. The NETTS team completed permitting and site identification for a prototype biodiesel process project and supported an adjustable depth air sparging system feasibility study. Finally, NETTS supported EPA multi-level and ESTCP long-term monitoring sampling events and supported University of Connecticut flux measurements. Information on NETTS demonstrations can be found at http://enviro.nfesc.navy.mil/erb/support/netts/main.htm.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Dover AFB, DE; CU-866

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Tim McHale, Naval Facilities Engineering Service Center, Dover AFB, DE

FY 2004 FUNDS: $510K

DESCRIPTION: This National Environmental Technology Test Sites (NETTS) National Test Location at Dover Air Force Base (AFB), which is managed by the Air Force Research Laboratory (AFRL), provides test sites for the application of characterization and remediation technologies for soil and water contaminated by chlorinated solvents. Its centerpiece is the Groundwater Remediation Field Laboratory (GRFL). The GRFL consists of isolated, well-monitored, in situ controlled release test cells, in which mass-balance studies of the fate, transport and remediation of dense non-aqueous phase liquids (DNAPL) may be performed. Operations consist of long-term compliance monitoring of the site and infrastructure maintenance, as well as project support to include among other things injection and monitoring of the test constituents (primarily trichloroethylene and perchloroethylene), demonstration of innovative technologies, some analytical support to demonstrators, and management and disposal of a minimal amount of waste from the tests. The process for obtaining permits for contained releases is established. In addition to supporting the contained release test cells and accompanying infrastructure, several demonstrations located in existing plumes on Dover AFB are given significant field and laboratory support. More recently, the Dover National Test Site (DNTS) has undertaken research initiatives to address concerns over a methyl tert-butyl ether (MTBE) plume that has migrated onto the Base boundary. The State of Delaware regulatory branch requested a corrective action from Dover AFB. As a result, several cooperative efforts between Dover AFB, the DNTS, and the U.S. Geological Survey have culminated to produce an MTBE Technology Demonstration Program.

BENEFIT: The GRFL is a unique resource, the primary purpose of which is to provide contained release cells for DNAPL research and development that avoid making the gross assumptions that would be necessary if experiments were conducted in previously contaminated aquifers. DNAPLs are immiscible with and denser than water, and when spilled on the ground, migrate below the water table. Once below the water table, they are difficult to locate and remove.

ACCOMPLISHMENTS: Since its inception, the DNTS has supported innovative technology demonstrations ranging from plume characterization and monitoring techniques to remediation of chlorinated solvents and fuel components. Transfer of the DNTS to the Navy was a significant accomplishment. DNTS was issued a new permit to operate and maintain a groundwater remediation field laboratory. This permit allows the injection of up to 100-liters of PCE into each test cell on site over the next 3 years. A key change incorporated into this new permit is the reduced frequency of compliance sampling from monthly to quarterly. Significant support was provided to two ESTCP efforts, Demonstration/Validation of Long Term Monitoring Using Direct Push Technology and Biodegradation of DNAPLs Through Bioaugmentation of Source Materials. A DNTS web site (http://www.dnts.org/) and interactive CD have been developed.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Bioreduction and Removal of Ammonium Perchlorate; CU-1162

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Coates, University of California, Berkeley, CA

FY 2003 COMPLETED PROJECT

DESCRIPTION: This project provided a better understanding of the microbiology involved in perchlorate reduction and removal. The factors controlling the applicability of microorganisms to the in situ treatment of ammonium perchlorate contamination of natural water supplies were determined. This work also assisted in the development of protocols and molecular tools required for the modeling and application of in situ bioremediation strategies to treat perchlorate contamination in the environment. The objectives were addressed under the following hypotheses: (1) Perchlorate-reducing bacteria are ubiquitous and indigenous in perchlorate contaminated environments; (2) All perchlorate-reducing bacteria contain a conserved chlorite dismutase (CD) enzyme; (3) Indigenous microbial perchlorate reduction can be easily stimulated in contaminated environments; (4) Stimulated perchlorate reducing populations can remove perchlorate concentrations to levels significantly lower than 18 μg/L; (5) Rates of microbial perchlorate reduction will be affected by the environmental conditions; and (6) Stimulated perchlorate-reducing populations will also enhance biodegradation of co-contaminating organics.

BENEFIT: Results from these studies provide a better understanding of the microbiology involved in perchlorate reduction and the factors controlling the activity of these organisms. These studies also allow the development of a molecular probe that is specific for all perchlorate-reducing bacteria. Such a probe can be used for predictive determinations of the success of a biological in situ treatment process and also as a monitoring tool for intrinsic or enhanced bioremediative efforts. Finally, this study identified the potential of a stimulated perchlorate-reducing population.

ACCOMPLISHMENTS: Enumeration studies of perchlorate-reducing bacteria that were performed on samples collected from a broad diversity of environments have demonstrated that microbial perchlorate reduction is ubiquitous. More than thirty chlorate-reducing bacteria have been isolated and characterized, and the dominant groups found in most environments have been identified. A perchlorate-reducing organism capable of anaerobic degradation of benzene was isolated and fully characterized, demonstrating for the first time that organic contaminant degradation could be coupled to perchlorate reduction. A culture collection for dissimilatory perchlorate-reducing bacteria (DPRB) was established. Kinetic studies in pure culture indicated that the CD enzyme is essential for the reduction of (per)chlorate, as it catalyzes the dismutation of toxic chlorite into chloride and oxygen. CD expression is not constitutive, and the active enzyme is only present under certain environmental conditions. The presence of oxygen inhibits the expression of an active CD enzyme. Perchlorate is required for the induction of an active CD enzyme. The presence of nitrate inhibits the expression of an active CD enzyme and perchlorate reduction only in organisms that grow by nitrate reduction. Perchlorate reduction is also dependent on molybdenum. Batch culture experiments with several pure cultures indicated that all perchlorate-reducers tested can remove perchlorate levels to below detection under ideal conditions. The CD gene was isolated and sequenced and now can be used as a gene probe. An immunoprobe specific to the CD enzyme has also been developed. A chemotactic response of DPRB was identified, and the ability of DPRB to fractionate stable isotopes of chlorine was demonstrated.

TRANSITION: All results have been published in peer reviewed journals. A website has been developed to document the results, tools, and techniques produced. Research has resulted in 4 patent applications, which have attracted the interest of several biotechnological/bioremediation companies.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Extraction Tests for Determining the Bioavailability of Metals in Soil; CU-1165

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Ruby, Exponent Environmental Group, Boulder, CO

FY 2004 FUNDS: $17K

DESCRIPTION: The primary objective is to develop a suite of simple and easy-to-use extraction tests to predict human and ecological exposures to metals in soil. Such tests will provide inexpensive and rapid tools for establishing the bioavailability of metals in soils at hazardous waste sites. Soils used in the project will be characterized for metal species and soil parameters to provide a mechanistic basis for any differences in metals bioavailability among the samples. Therefore, results will also provide an understanding of how various species of a metal may differ in bioavailability, and also how various soil properties may affect metals bioavailability and the stability of the measured bioavailability estimates. An extraction technique developed by Exponent has already been demonstrated to predict human oral exposure to lead, arsenic, and other metals in soils. A research consortium founded by Exponent is currently completing validation of this method for lead, and working on validation of the method for arsenic. This project will extend application of this technique to other metals of concern. The results should also be applicable to assessing exposures of terrestrial mammals in ecological risk assessments. The project will include an evaluation of method parameters that might be modified to better predict relative bioavailability of metals in soil in different kinds of mammals. A second aspect of the project will focus on assessing dermal absorption of arsenic and cadmium from soil.

BENEFIT: The most promising tests for quantifying the bioavailability of metals from soil are extraction tests that measure the fraction of a metal that is soluble and available for absorption. Once developed, these simple tests will be useful for assessing metals bioavailability during site assessment, evaluating any changes to bioavailability after remediation or restoration, and studying the long-term stability of metal species in amended soils.

ACCOMPLISHMENTS: The researchers completed an evaluation of which metals occur as contaminants and drive remediation activities at DoD sites most often. Soil characterization was completed for several of the soils used in arsenic bioavailability tests, cadmium bioavailability tests, and the wildlife bioavailability studies. Avian relative oral bioavailability studies using the American robin as the receptor were completed and a protocol was developed and approved. Mammalian relative oral bioavailability studies using the least shrew as the receptor species were completed, and analytical results have been obtained. A protocol for measuring dermal absorption of arsenic in Rhesus monkeys was developed and approved. An intravenous dose and dermal application of arsenic in solution has been completed under shared funding. Also, a study of dermal arsenic absorption from chromated copper arsenate (CCA) treated wood was completed. Researchers prepared a study design for assessing dermal absorption of cadmium using cadaver skin, and then conducted a pilot study. A protocol for assessing the oral bioavailability of arsenic in Cynomolgus monkeys was prepared and approved. Dosing of monkeys by gavage was initiated. The study of oral bioavailability of cadmium in young swine was completed. The protocol was developed and approved, and four cadmium containing soils have been tested.

TRANSITION: A suite of simple extraction tests will be available to DoD personnel for site-specific evaluation of metals bioavailability from soil at field sites and will result in more accurate exposure and risk estimates that are still protective of human health and the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Foam Delivery of Hydrogen for Enhanced Aquifer Contacting and Anaerobic Bioremediation of Chlorinated Solvents; CU-1203

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Hirasaki, Rice University, Houston, TX

FY 2003 COMPLETED PROJECT

DESCRIPTION: Hydrogen sparging of aquifers contaminated with chlorinated solvents has been shown to enhance microbial dechlorination in situ. The major concern in the application of this remedial approach is the ability to distribute hydrogen effectively throughout the contaminated interval such that complete dechlorination can occur. A promising method to improve hydrogen contact throughout a contaminated interval and to greatly extend the horizontal migration of hydrogen in the subsurface is to deliver the hydrogen as an "in situ generated foam" - a dispersion of gas in water that is stabilized from coalescence by the presence of a small amount of surfactant. The objective of this effort was to investigate the ability of hydrogen-foams to more effectively contact aquifer sands, thereby supporting rapid dechlorination activity compared to conventional hydrogen sparging. The foam was generated by injection of a slug of dilute surfactant solution into the well, followed by gas injection. The gas bubbles that formed were inhibited from coalescence by the surfactant adsorbed at the interfaces, and the lamellae or "soap films" between the bubbles increased the resistance of the gas to flow through porous media.

BENEFIT: The expected benefit of hydrogen delivery as foam is increased well spacing and decreased frequency of sparging. If foam can increase the distance that hydrogen contacts the base of the aquifer from 3 feet to 15 feet, the area of the base of the aquifer contacted by hydrogen may increase by a factor of 25. Alternatively, an aquifer can be remediated with 1/25 as many wells if foam improves the aquifer contact by the amount of this illustration. If the residual hydrogen gas saturation after sparging is increased, a longer amount of time will pass before the hydrogen is depleted and sparging needs to be repeated. Thus, foam delivery of hydrogen may reduce the frequency of sparging per well. If the trapped gas saturation in the contacted region is increased from 10% to 50%, the frequency of sparging per well can then be reduced by a factor of 5. Combined with a reduced number of wells required to conduct the remediation, the frequency of sparging a well in the entire project can be reduced by a factor of 125.

ACCOMPLISHMENTS: The model UTCHEM was used to simulate foam injection in an Experiment Controlled Release System (ECRS) tank. The performance of water/air and surfactant solution/air injection in the ECRS tank indicated that additional work was needed to predict field performance. The effectiveness of foam to distribute and trap gas was then evaluated in a three-dimensional (3D) ECRS tank. Numerical simulations which compared the foam strength in the ECRS tank and the one-dimensional (1D) column experiment, showed that the foam was about 10,000 times weaker in 3D as compared to the 1D column. The anionic surfactants, which were effective for foaming, were found to inhibit the dechlorination of *cis*-DCE. However, perchloroethylene (PCE) and trichloroethylene (TCE) were still rapidly dechlorinated in the presence of the surfactants.

TRANSITION: The studies were designed to yield the information required for field applications. Results will be provided to DoD stakeholder and industrial affiliates for incorporation into ongoing cleanup projects. Site-specific design and site characterization for the use of hydrogen-based foams is beyond the scope of this project. Therefore, this project intends to transition through the ESTCP.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Permeable Reactive Barriers Using Edible Oils; CU-1205

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Borden, North Carolina State University, Raleigh, NC

FY 2004 FUNDS: $30K

DESCRIPTION: Permeable reactive barriers (PRBs) are being considered at many sites because they are expected to have much lower operation and maintenance (O&M) costs than active pumping systems. As solvents or other contaminants migrate through the barrier, the contaminants are removed or degraded, leaving uncontaminated water to emerge from the downstream side. This project will develop and evaluate an alternative barrier system for controlling the migration of chlorinated solvents. An oil-in-water emulsion will be prepared using food-grade edible oils, then injected into the contaminated aquifer in a barrier configuration using either conventional wells or Geoprobe points. As the emulsion passes through the aquifer, a portion of the oil becomes entrapped within the pores leaving a residual oil phase to support long-term reductive dehalogenation of chlorinated solvents that enter the barrier.

BENEFIT: Edible oil barriers have tremendous cost and operational advantages over competing technologies including zero valent iron barriers and anaerobic bioremediation using soluble substrates. Construction costs for zero valent iron barriers are typically in the range of $100 per square foot of barrier. In comparison, installation of a 40 ft deep by 200 ft wide edible oil barrier is estimated to cost less than $100,000 or approximately $15 per square foot of barrier. If the edible oil barrier technology can be adequately developed, this approach has the potential to significantly reduce the cost and improve the effectiveness of aquifer remediation for chlorinated solvents and a variety of other contaminants including nitrate, chromate, and oxidized radionuclides.

ACCOMPLISHMENTS: A method for distributing emulsified edible oils in a variety of aquifer materials without excessive permeability loss was developed. A mathematical model based on colloid transport theory for simulating the transport and retention of these emulsions was also developed. Effective emulsion transport and distribution in three-dimensional (3D) sandbox experiments was demonstrated. The emulsion transport model using experimental results from one-dimensional (1D) columns and the 3D sandbox was validated. The effective treatment of dissolved PCE using emulsified oils in flow through column experiments was demonstrated, and a variety of alternative substrates that can be used to control the biodegradation rate were identified.

TRANSITION: Results will be presented at research symposia and in peer-reviewed journals and will be shared with practitioners currently using the edible oil process at field sites. Three companies are conducting demonstrations of the edible oil process at Air Force Bases (AFBs) around the U.S. These companies are actively marketing the edible oil process to public and private clients. Laboratory results obtained in this project will be implemented in the field demonstrations being conducted for ESTCP and the Air Force Center for Environmental Excellence (AFCEE). As a consequence, results will be rapidly communicated to the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Stabilization of Persistent Organic Contaminants in Marine Sediments; CU-1207

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Luthy, Stanford University, Stanford, CA

FY 2003 COMPLETED PROJECT

DESCRIPTION: The research team investigated the feasibility for in situ stabilization/containment of persistent hydrophobic organic compounds (HOCs) in sediments through the use of low-dose, coal-derived material, such as coke, as sorbent media to sequester persistent organic contaminants. Previous research had shown that coal-derived materials are strong sorbents that may capture organic contaminants and make them unavailable in the aqueous phase and unavailable for biological uptake. Coal-derived and coaly, particulate sorbent media are two-to-three orders of magnitude more efficient in sequestering HOCs compared to natural sediment organic matter. Thus, the addition of fresh coal-derived sorbents to contaminated sediments would reduce ecosystem exposure by reducing contaminant flux between sediments, pore water, and the water column. Owing to the extreme temperatures employed during manufacture, coal-derived sorbent media like coke is free of volatile materials such as polycyclic aromatic hydrocarbons (PAHs) and is therefore not a regulatory concern. Novel whole-sample, particle-scale, and subparticle-scale techniques will be used to assess the efficacy of the stabilization technology. These techniques allowed the distribution and relative availability of organic contaminants among sediment component materials to be identified. The research team monitored how effective the coal-derived material was at capturing and binding the readily available fraction of the PAH and polychlorinated biphenyl (PCB) contaminants. The team tested various low-cost materials, including coke and char, and compared the results with those of activated carbon. The research team monitored the success of the stabilization process by spectroscopic and spectrometric measurements and by survival and growth of organisms currently used to develop chronic, sublethal, marine sediment bioassays for national regulatory programs. Finally, the team investigated the feasibility of the technology for in situ stabilization of PAH and PCB contaminants found in marine sediments.

BENEFIT: HOCs such as PAHs and PCBs are important contaminants of concern to the DoD. These contaminants associate with fine grained, organic-rich material in sediment and are long-lived. Sediment serves as a contaminant reservoir from which fish and bottom-dwelling organisms can accumulate toxic compounds like PCBs that are then passed up the food chain. Cost-effective and efficient technologies for contaminated sediment management can significantly reduce the expenditure on environmental restoration and achieve the DoD environmental security goals and objectives. The potential benefit of this work is the attainment of in situ contaminant management by means of a cost-effective and non-removal technology resulting in stabilization to significantly reduce contaminant bioavailability.

ACCOMPLISHMENTS: Tests were conducted to investigate the effect of activated carbon dose on the reduction in PCB bioavailability. Hunters Point sediment was treated with different amounts of activated carbon for one month. After contact, these sediments were used for physicochemical tests of PCB availability and biological uptake measurements. The physicochemical tests involving aqueous equilibrium partitioning of PCBs, uptake in semipermeable membrane devices, and flux into overlying water were completed.

An experimental setup using a vibrating grid mechanism was used to investigate the effect of bottom shear on resuspension of sediments and activated carbon. Sediments from Hunters Point South Basin were tested in the resuspension experiment before and after mixing with carbon to evaluate the relative potential of resuspension of added activated carbon as a function of bottom shear. These results were compared with expected bottom shear values for the Hunters Point South Basin area. Rates of adsorption of PCBs onto activated carbon were measured in laboratory batch experiments.

TRANSITION: Results provide a proof of concept of the in situ containment technology and a scientific basis for the support of field implementation of the technology. This research should lead to a future pilot scale demonstration project at a DoD marine site. Partners within this program will publish in peer-reviewed journals and will present information at national and international symposia and informal briefings at DoD, Navy, Army, U.S. Army Corps of Engineers (USACE), and EPA offices. Results will also be presented in a series of Engineer Research and Development Center (ERDC) reports, utilizing a functional format to encourage demonstration and implementation beyond the proof-of concept-stage. The reports will include information such as process mechanisms, application protocol, process economics, technical points of contact, and process limitations.

PROJECT SUMMARY

PROJECT TITLE & ID: In Situ Enhancement of Anaerobic Microbial Dechlorination of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Marine and Estuarine Sediments; CU-1208

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Max Haggblom, Rutgers University, New Brunswick, NJ

FY 2004 FUNDS: $152K

DESCRIPTION: Application of bioremediation to polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F)-contaminated marine and estuarine sediments is currently severely limited by the lack of fundamental knowledge about the microorganisms responsible for their degradation, including anaerobic reductive dechlorination. The research team will characterize the PCDD/F dechlorinating capability of native dehalogenating bacteria from different estuarine and marine sites. Enrichments developed from these sites and an existing dioxin-dechlorinating culture will be used to assess how PCDD/F dechlorination can be stimulated and accelerated under different terminal electron accepting conditions (methanogenic, sulfate-reducing, and iron-reducing) relevant to marine sediments. A variety of intensive amendment strategies will be tested to enhance reductive dechlorination including addition of alternative halogenated primers such as bromophenols; co-amendment with hydrogen, hydrogen donors, and other electron donors; and manipulation of the terminal electron-accepting processes.

BENEFIT: An improved fundamental understanding of dehalogenating bacterial communities that dechlorinate PCDD/Fs in marine and estuarine sediments and how these communities are affected by redox conditions and addition of primers and amendments will be gained. Data collected will be used for the development of conceptual and biological process models to describe and predict the effect of different enhancement methods on the terminal electron accepting process and microbial populations. These findings will result in development of methodologies to assess the potential for PCDD/F dechlorination at specific sites that could result in savings for costly sediment restoration projects.

ACCOMPLISHMENTS: During FY 2003, the project team demonstrated the effectiveness of alternative halogenated compounds for enhancing dechlorination of 1,2,3,4-tetrachlorobenzene/1,2,3,4-tetrachlorodibenzofuran (1,2,3,4-TeCDD/F) in marine and estuarine sediments. The most effective stimulation of 1,2,3,4-TeCDD dechlorination was accomplished by addition of the halogenated additives 1,2,3,4-tetrachlorobenzene, 2,3,4,5-tetrachloroanisole, 2,3,4,5-tetrachlorophenol or 2,3,4-trichloroacetophenone with lactate and propionate as electron donors. Dechlorination of 1,2,3,4-TeCDF to tri-, di- and mono-chlorinated daughter products was also significantly enhanced by the addition of 1,2,3,4-tetrachlorobenzene and 2,3,4-trichloroacetophenone. These results suggested that halogenated aromatic compounds with structural similarity to 1,2,3,4-TeCDD/F stimulate bacteria with the ability to dechlorinate chlorinated dibenzo-p-dioxin and furans. In conjunction with Stephen Zinder at Cornell University, the team demonstrated that Dehalococcoides ethenogenes strain 195 is capable of dehalogenating chlorinated dioxins and furans. Tetrachloroethene was dechlorinated to vinyl chloride and ethene within two weeks in all cultures, demonstrating that the cultures remained viable and active throughout the incubation period.

TRANSITION: This project will develop methodologies for monitoring in situ bioremediation of contaminated sediments, including identification of specific amendments and environmental conditions that prime and/or accelerate the dechlorination of PCDD/Fs. Peer-reviewed articles and conference presentations will transfer findings to the scientific community for future application.

PROJECT SUMMARY

PROJECT TITLE & ID: Pathway Interdiction: A System for Evaluating and Ranking Sediment Contaminant Transport Pathways in Support of In-Place Management; CU-1209

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bart Chadwick, Space & Naval Warfare Systems, San Diego, CA

FY 2003 COMPLETED PROJECT

DESCRIPTION: Many of the contaminated marine sediment sites currently under investigation are in shallow, coastal areas and are much more likely than more traditionally studied offshore sediments to be impacted by advective processes such as groundwater flow, tidal pumping, wave pumping, and by resuspension via ship and storm activity. While these processes are recognized in the oceanographic community as having significance to chemical fluxes, they are largely unstudied in contaminated systems, and the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation have not been determined. If contaminants are to be left in place, it is critical to evaluate potential pathways by which contaminants might pose an ecological or human health risk and to monitor, minimize, or eliminate these pathways. This effort sought to apply an integrated suite of methods for the direct characterization of these dynamic transfer pathways for contaminants in sediments. Methods for the quantification of mechanisms, magnitudes, and directions of porewater-mediated contaminant transport were integrated with sediment/contaminant geochemical characteristics, hydrodynamically-driven particle transport, and biological processes. While each of these processes had been examined individually, they had never been examined together such that they could be ranked and compared to support in-place sediment management.

BENEFIT: Diagnostic tools for characterizing and quantifying potential in-place contaminant pathways will aid in the selection, permitting and monitoring of in situ management strategies. The payoff for a demonstrated, systematic process for measuring and evaluating contaminant transport pathways within sediment systems in support of in-place management is twofold (1) by providing solid, measurement-based information on contaminant fate which results in the permitting of in-place management, the savings can be millions of dollars per site, and (2) since pathways of contaminant transport in place can be directly measured, the ecological risk of leaving sediments in place will be reduced.

ACCOMPLISHMENTS: During FY 2003, methods and models for integrating results from measurement-specific reports into flux equations were developed, refined and evaluated. Contaminant fluxes from Site I (Paleta Creek, San Diego, CA) were evaluated in the model to determine the dominant drivers of contaminant transport at Site I. The numerical analysis was completed, and the results were evaluated in terms of various assumptions about contaminant fate, behavior, and risk. An integrated field deployment at Site II (Pearl Harbor, HI) was completed, and the chemical and physical analyses from sediment, seawater, and porewater samples were completed.

TRANSITION: Site-specific and pathway-specific information have been disseminated via peer-reviewed journals, professional scientific and technical meetings, and technical reports. All work was carried out at sites undergoing remedial investigation or management, in collaboration with Remedial Program Managers (RPMs), regulators and stakeholders. Transition via the Remediation Technology Development Forum, Sediment Working Group and the Sediment Management Work Group will be sought. This project intends to transition through the ESTCP.

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Bioavailability, Toxicity, and Bioaccumulation of Organic Chemicals and Metals for the Development of Eco-SSLs; CU-1210

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Lanno, Ohio State University, Columbus, OH

FY 2003 COMPLETED PROJECT

DESCRIPTION: The goal of this research was to identify and characterize the predominant soil physical/chemical parameters that modify the bioavailability, bioaccumulation, and/or toxicity of trinitrotoluene (TNT), trimethylenenitramine (RDX), polynuclear aromatic hydrocarbons (PAH), and selected metals in soil invertebrates and plants. Exposure concentrations were measured as total chemical levels and as the labile portion that is presumed to be bioavailable. Both of these chemical measures were correlated with toxicity endpoints (e.g., growth, reproduction) and bioaccumulation with the ultimate goal of developing models relating soil chemistry parameters to bioavailability, bioaccumulation, and toxicity.

BENEFIT: Development of an empirical model relating soil physical/chemical characteristics to the bioavailability, bioaccumulation, and toxicity of TNT, RDX, PAHs, and selected metals to soil invertebrates and plants will allow the incorporation of bioavailability into the development of Ecological Soil Screening Levels (EcoSSLs) by facilitating estimation of bioavailable levels of chemicals from literature data where only total chemical and soil physical/chemical characteristics are presented. Current chemical methods for estimating bioavailability have been correlated with biological responses of macroinvertebrates and plants in very few studies. This research is developing these correlations, thereby validating chemical estimates of bioavailability in soils. Validation of chemical measures of bioavailability would provide another tool that can be used in early-tier screening of contaminated soils during ecological risk assessment. A large data set consistent with respect to quality assurance/quality control (QA/QC) procedures and data criteria has been generated that can be used to develop EcoSSLs for the rapid initial screening of contaminated DoD, DOE, and EPA sites. This will allow the removal of low-risk sites from further ecological risk assessment and allow efforts and resources to be focused on sites that present an unacceptable risk.

ACCOMPLISHMENTS: During FY 2003, definitive earthworm and potworm toxicity tests and data analyses for TNT and RDX in freshly amended and weathered/aged amended soils were completed. The team completed collembolan definitive toxicity tests for TNT in freshly amended and weathered/aged amended soils. Weathering and aging of soils amended with RDX for use in definitive soil invertebrate and plant toxicity assays were completed. Definitive plant metal uptake and bioaccumulation studies also were completed for Ryegrass, Japanese Millet, and Alfalfa in arsenic, lead, cadmium, and zinc spiked soils.

TRANSITION: Both Principal Investigators are involved with the EPA Steering Committee for the development of EcoSSLs and therefore provide a direct conduit for the application of data generated during this research in the development of EcoSSLs. In turn, EcoSSLs generated with data provided from this project can be used in the screening of soil contamination at DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Bacterial Degradation of DNT and TNT Mixtures; CU-1212

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rebecca Parales, University of California, Davis, CA

FY 2004 FUNDS: $330K

DESCRIPTION: The major objective of this effort is to characterize bacterial strains with the ability to efficiently degrade mixtures of dinitrotoluene (DNT) isomers and to expand the degradative capability to include 2,4,6-trinitrotoluene (TNT). This research team has isolated bacteria that can degrade both 2,4- and 2,6-DNT and will carry out physiological and genetic studies with those strains to determine whether the DNT isomers are degraded simultaneously or sequentially and how the genes encoding the pathways are regulated. The pathways, enzymes, and inducing molecules will be characterized. Team members will characterize the novel enzymes and the product(s) of TNT oxidation and screen for ring cleavage enzymes that can destroy the oxidized TNT molecule. The TNT dioxygenase and appropriate ring cleavage dioxygenases genes will be introduced into strains that degrade both isomers of DNT. The resulting strains will be tested for the ability to eliminate the toxicity of synthetic mixtures of DNT and TNT. The strains will be inoculated into microcosms containing contaminated soil from Volunteer Army Ammunition Plant and the degradation of DNT and TNT will be monitored.

BENEFIT: Bioremediation is expected to reduce the cost of remediation by $60M over previous estimates for Badger Army Ammunition Plant. Although preliminary results are encouraging, there is an urgent need to understand the regulation and degradation of mixtures. Previous experiments have revealed that 2,4-DNT could be degraded readily in soil and water from Volunteer although TNT and 2,6-DNT were problematic. The new insight about degradation of mixtures including TNT will be directly applicable to the future cleanup at Volunteer and at other TNT manufacturing sites. The research team proposes to generate recombinant organisms for the degradation of nitroarene compounds although field application of the basic discoveries to be made under this project is several years away. Cleanup of in situ and excavated soil both in the U.S. and abroad should benefit considerably from novel microbial strategies for TNT and DNT degradation.

ACCOMPLISHMENTS: To date, the project team has isolated and characterized several bacterial strains that grow with 2,4-DNT, 2,6-DNT, or both DNT isomers. The molecular biology and enzymatic steps of the 2,4-DNT pathway in Burkholderia cepacia R34 were fully characterized. The team demonstrated the oxidation of aminodinitrotoluenes by nitroarene dioxygenases, and identified the products as specific aminonitrocatechol isomers. The regulation of the nitroarene dioxygenase genes in the nitrobenzene- and 2-nitrotoluene-degrading strains Comamonas sp. JS765 and Acidovorax sp. JS42 was characterized, demonstrating that salicylate, several nitroarene compounds, and 2amino46DNT and 4-amino26DNT are inducers. Nitroarene dioxygenase gene clusters from two 2,6-DNT degrading strains and one dual-DNT degrading strai were cloned and sequenced. A sequence of the DNT catabolic plasmid from Burkholderia sp. strain DNT and compared the gene order to that in Burkholderia cepacia R34 was generated. The optimized DNT and aminoDNT dioxygenase enzymes by DNA shuffling were completed. The team continued screening for ring-fission dioxygenases that catalyze the cleavage of aminonitrocatechols produced by the action of nitroarene dioxygenases on aminoDNTs.

TRANSITION: Gains achieved by the research team will be rapidly incorporated into ongoing cleanup strategies and implemented in new cleanup efforts–particularly at Badger and Volunteer. In addition, two private companies have contacted the research team to explore the feasibility for cleanup of DNT contaminated industrial sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Microbial Degradation of RDX and HMX; CU-1213

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari, Biotechnology Research Institute, Montreal, Quebec CANADA

FY 2003 COMPLETED PROJECT

DESCRIPTION: Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) are powerful highly energetic chemicals whose widespread use has resulted in severe soil and groundwater contamination. Efforts over the past two decades to decontaminate soil and groundwater by biological means have failed because the microbial processes and enzymes involved in degradation are poorly understood. Recently, this research team has discovered that both RDX and HMX can be mineralized under both aerobic (P. chrysosporium and the soil isolate Rhodococcus sp.) and anaerobic conditions (municipal anaerobic sludge) to nitrous oxide and carbon dioxide despite some previous reports that RDX is not mineralized under these conditions. For example, it has been demonstrated that once RDX undergoes an initial biological attack the molecule autodecomposes. The mechanism leading to mineralization is unknown; however, several testable hypotheses exist regarding how mineralization proceeds. These hypotheses were tested by conducting fundamental laboratory experiments to identify the enzymes that cause the molecules to disintegrate and to investigate the subsequent biochemical decomposition reactions. In addition, the team identified intermediate degradation products and study the kinetics and stoichiometry of their formation.

BENEFIT: Although this research was intended to generate the fundamental knowledge needed to understand the enzymatic processes involved in the microbial degradation of RDX and HMX, the results can be used to enhance bioremediation and facilitate future field application. When the degrader(s) and enzyme(s) (reductase, hydrolase or oxygenase) responsible for the initial reaction on the cyclic nitramine explosive in liquid media are discovered, it will be possible to design effective field treatment strategies. Therefore, the inclusion and the design of bench scale experiments using soil from contaminated sites will generate the knowledge required for future field demonstration and application. For example, knowledge of degradation mechanisms will allow prediction and enhancement of biodegradation. Insight regarding microbial and enzymatic processes together with their degradation products can be used by site managers and engineers as monitoring tools to understand the fate of explosives after removal.

ACCOMPLISHMENTS: The research team elucidated the pathway of microbial degradation of RDX and HMX. The team discovered that once RDX and HMX undergo an initial biological attack, the molecule autodecomposes to produce nitrous oxide and carbon dioxide. Prior to this research, while it was generally known that anaerobic and aerobic degradation of these compounds was feasible, neither the microorganisms nor enzymes that initiated the degradation were known. In the course of understanding the enzymatic and microbial processes involved in attaining autodecomposition, key microbial metabolites and two intermediates providing new insights into their degradation pathways were discovered.

TRANSITION: Successful lab-scale microcosms for the degradation of RDX and HMX provide the basis for pilot-scale-up work to identify engineering parameters for field demonstration and application. Results of this project have been disseminated in such a manner that facilitates future investigations.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Pathways of Nitroaromatic Metabolism: Hydroxylamine Formation, Reactivity, and Potential for Ring Fission for Destruction of TNT; CU-1214

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joseph Hughes, Georgia Institute of Technology, Atlanta, GA

FY 2004 FUNDS: $65K

DESCRIPTION: Independent studies conducted by members of this research team have converged at the discovery of a similar and novel metabolic pathway that yields products from 2,4,6-trinitrotoluene (TNT) that no longer display aromatic characteristics. It should be possible to exploit this pathway in the development of improved TNT treatment methods, where the destruction of TNT is achieved and the process is carried out in situ. The goals of this effort are to determine the biochemical mechanism of TNT ring fission and to use this fundamental information to develop strategies that harness the activity in remediation systems. Specific objectives include: (1) Identify the products of the novel TNT transformation pathway that no longer display aromatic characteristics, (2) Determine the mechanism of ring fission and identify the enzymes responsible, (3) Characterize the properties of the enzymes and their regulation, (4) Develop strategies to direct TNT metabolism to ring fission products, and (5) Validate the destruction of TNT in lab-scale microcosm testing where mass balances and toxicity reduction can be determined.

BENEFIT: Studies will yield an improved understanding of the microbial processes involved in the degradation of nitroaromatic compounds. Based on the initial work, it should be possible to develop in situ treatment methods where the destruction of TNT is achieved. Strategies involving reduction only to the hydroxylamine level with subsequent rearrangement and ring fission would require far less carbon addition and less dramatic shifts in redox potential than conventional strategies for TNT cometabolism. The potential to drive TNT to non-aromatic end points has been demonstrated in two widely different microbial systems, and it occurs at high rates. If demonstrated that this novel metabolism can be induced and sustained in situ, the development of low-cost remediation systems will be possible.

ACCOMPLISHMENTS: Work at Air Force Research Laboratory (AFRL) continued to focus on isolation and identification of intermediates suspected to lead to biotic ring fission. The project team determined that the yellow metabolite is formed via two different pathways, one that goes through 2,4-dihydroxylaminonitrotoluene (DHANT), and another that proceeds through 2-amino-4,6-dinitrotoluene (2ADNT). Conflicting evidence hampered the understanding of the role of the nitrobenzene degradation enzymes involved in TNT transformation. The genes for the key enzymes involved were cloned into an E. coli host and placed under the control of a promoter. The resulting strains were used to clarify the roles of the key enzymes in TNT transformation and to make sufficient quantities of TNT transformation products for isolation and identification.

TRANSITION: Microcosms will be conducted with soils from the Volunteer Army Ammunition Plant and the Alabama Army Ammunition Plant. Results will be provided to collaborators for incorporation into ongoing cleanup projects. This project intends to transition through ESTCP for further optimization of process parameters.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Technology for Wide-Area Screening of ERC-Contaminated Soils; CU-1228

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Colin Cumming, Nomadics, Inc., Stillwater, OK

FY 2003 COMPLETED PROJECT

DESCRIPTION: Nomadics developed an advanced landmine detection capability based on use of an amplifying fluorescent polymer (AFP) sensing technology. In order to ensure detection of a mine by soil sampling, Nomadics demonstrated that sufficient soil must be sampled in a spatially distributed fashion around the mine. The sensor detects ultra-low concentrations of explosives in the headspace above mines and in the soils close to mines. The AFP-based detection technology is primarily focused on nitroaromatic compounds. Some of these are contaminants derived from the explosive-related compounds (ERCs), while others are formed through biodegradation and photochemical degradation of the ERCs. The amplifying polymer responds primarily to electron-deficient aromatic compounds. This technology is sensitive to analyte concentrations 5 to 6 orders of magnitude lower than the currently fielded soil analysis technologies. This project evaluated the relevance of the soil sampling and detections methods developed for landmine detection to wide area screening, then sought to develop and evaluate a novel standoff approach based on the use of the AFP sensing technology.

BENEFIT: By combining such a high sensitivity detector with an advanced high-speed sampling system, rapid and reliable wide-area screening is possible. Nomadics has developed an electrostatic precipitator-based soil sampling system that can uniformly capture small soil particles rapidly, such that large areas can be sampled efficiently and confidently. The transduction amplification capability of the polymer makes other deployment scenarios possible as well, including true standoff detection. If the method is successful, costs for screening ranges will be greatly reduced based on the need for fewer samples to cover a large area. The cost of analysis per sample is much less than for currently accepted laboratory methods, further decreasing costs. Since samples will be analyzed in the field, the turn around time for results will enable rapid decisions relating to the level of contamination, and therefore suitability of a range for continued use (or possible need for remediation efforts), to be made on-site.

ACCOMPLISHMENTS: During FY 2003, the team made significant mechanical improvements to the high volume vapor cartridge design. The team performed an initial laboratory characterization of 20 different amplifying fluorescent polymer formulations. There were significant optical improvements made to the fluorescent bead imaging system. The project team performed experiments correlating 2,4,6-trinitrotoluene (TNT) diffusion to polymer film thickness. Differences in bead performance using glass and styrene-divinylbenzene material were investigated. It was determined that the bead and optics system could not be effectively used in daylight conditions due to rapid photodegradation of the polymer. The team also spiked three types of soils with TNT over a range of concentrations. Measurement of the vapor signature as a function of soil type, soil moisture content, soil temperature, and soil TNT concentration was completed.

TRANSITION: Nomadics will work with collaborators and users to fully explore potentially new and powerful wide-area search paradigms based on ultrasensitivity and speed. Nomadics has taken several technologies and products from the laboratory into commercial sales. As the technology matures and is ready to move forward into production, Nomadics will work with other Defense contractors to ensure that the technology transitions into production. The researchers plan to transition this technology to ESTCP.

PROJECT SUMMARY

PROJECT TITLE & ID: Fe^0-Based Bioremediation of RDX-Contaminated Groundwater; CU-1231

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pedro Alvarez, University of Iowa, Iowa City, IA

FY 2003 COMPLETED PROJECT

DESCRIPTION: Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) is one of the most recalcitrant and toxic contaminants in the subsurface. This project worked develop a new and efficient method to remediate RDX-contaminated aquifers, based on combining a novel chemical process (reductive treatment with zero valent iron [Fe^0]) with a promising bioremediation approach (in situ reactive zones). This integrated Fe^0-microbial system is more than a mere juxtaposition of two technologies because Fe^0 and some microorganisms interact synergistically to degrade RDX. The objective of this project was to delineate the applicability and limitations of biologically-active Fe^0 barriers to manage RDX plumes. Through batch and column experiments, the research team: (1) verified that Fe^0 and anaerobic municipal sludge interact synergistically to mineralize RDX; (2) identified any soluble RDX-degradation products; (3) evaluated RDX removal in flow-through systems mimicking Fe^0 barriers and determined the effect of bioaugmentation on barrier permeability and efficiency; (4) determined how iron (III)-reducing bacteria modify the surface chemistry of oxides that passivate the Fe^0 surface; (5) characterized the structure of the microbial community colonizing iron samples; (6) determined how the Fe^0 surface area concentration affects RDX mineralization; and (7) determined how potential co- contaminants affect RDX removal efficiency.

BENEFIT: While the development of a cost-effective and sustainable remediation approach has great intrinsic merit, this project also has significant extrinsic merit related to enhancing the understanding of biogeochemical interactions in contaminated aquifers and the role of mineral surfaces in natural attenuation. This project provides a strong basis for designing reactive barriers to intercept exposure pathways associated with groundwater contamination by a wide variety of redox-sensitive contaminants.

ACCOMPLISHMENTS: During FY 2003, the project team continued to address the potential to enhance RDX degradation by bioaugmentation of a Fe^0 permeable reactive barrier (PRB). The subsequent degradability of unknown soluble byproducts formed during RDX transformation of batch and column systems were assessed. Such byproducts were mineralized faster and to a greater extent to carbon dioxide than the parent RDX compound. The flow-through column studies were continued to investigate the sustainability of these systems. The RDX degradation profiles for columns simulating permeable reactive iron barrier showed very high RDX removal efficiencies with no deterioration of hydraulic performance.

The capabilities of the facultative, dissimilatory iron reducing bacterium (DIRB) Shewanella alga BrY were investigated. New column experiments were completed to evaluate the capabilities of indigenous microbes present in soil down gradient of a PRB to mineralize any RDX metabolites that could break through the iron layer. These experiments evaluated and demonstrated the feasibility and robustness of an integrated PRB-natural attenuation integrated process.

TRANSITION: The project team is collaborating with other scientists and contractors at DoD sites to conduct controlled field demonstrations. The ultimate beneficiary will be the general public through improved risk management and enhanced environmental quality.

PROJECT SUMMARY

PROJECT TITLE & ID: Continuation of the Ecological Risk Assessment of Perchlorate and Explosives in Avian Species, Rodents, Reptiles, Amphibians and Fish: An Integrated Laboratory and Field Investigation; CU-1235

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Kendall, Texas Tech University, The Institute of Environmental and Human Health, Lubbock, TX

FY 2003 COMPLETED PROJECT

DESCRIPTION: The focus of this project was to continue to expand the knowledge base for environmental perchlorate and energetic contamination issues with field and laboratory studies designed to assess the associated ecological risks. The principal objective of this research was to examine the impact of environmental exposures of perchlorate and energetics (2,4,6-trinitrotoluene [TNT], hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX], and Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine [HMX]) on birds, rodents, fish, and amphibians. Bioavailability of perchlorate and energetics across trophic levels was evaluated, and toxicological impacts of perchlorate and energetics on exposed biota were assessed. Ecological receptors deemed to be at risk from exposure to perchlorate and energetics were identified through a number of inter-related sub-projects including analytical, terrestrial, and aquatic toxicology as well as ecological modeling.

BENEFIT: This program has resulted in the identification of ecological risks and in the development of models of exposure and toxicity that will be useful for the assessment of perchlorate and energetic contaminated sites and the evaluation of remediation techniques. Results will likely be used to establish regulatory standards and cleanup criteria for both perchlorate and energetics. The products will provide a framework of risk assessment methods and criteria necessary to define acceptable concentrations within ecological systems. These data will be useful in the characterization of DoD sites and sites potentially affecting valuable water supplies.

ACCOMPLISHMENTS: Research activities have identified exposure pathways, sensitive indicators of exposure, and an understanding of ecological impacts associated with perchlorate and energetics contamination. These studies have aided the development of analytical techniques and models of exposure and response that can be used to evaluate sites throughout the U.S. This research has resulted in numerous advances in the analytical chemistry of abiotic and biotic components of ecosystems, as well as a greater understanding of the subtle physiological alterations induced by perchlorate and energetic exposure.

TRANSITION: Information gained will be transitioned to agencies within the DoD, the EPA, and other federal and state agencies through reports and peer-reviewed publications.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Understanding of Fenton-Like Reactions for In Situ Remediation of Contaminated Groundwater Including Treatment of Sorbed Contaminants and Destruction of DNAPLs; CU-1288

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard J. Watts, Washington State University, Pullman, WA

FY 2004 FUNDS: $193K

DESCRIPTION: In situ chemical oxidation (ISCO) using modified Fenton's reagent (hydrogen peroxide and catalysts) holds the potential to rapidly treat many of the DoD sites that are contaminated with halogenated organic chemicals. Research suggests that modified Fenton's reagent used for ISCO is capable of rapid destruction of biorefractory contaminants, enhanced desorption of sorbed contaminants, and enhanced destruction of dense non-aqueous phase liquids (DNAPLs). This project aims to obtain a better fundamental understanding of modified Fenton's reagent as an ISCO process. Two principles serve as themes for the project. The first is that hydroxyl radicals, while necessary for the oxidation of soluble contaminants, are only partially responsible for the success of Fenton-like ISCO. The second is that naturally-occurring trace minerals may play an important role in Fenton-like ISCO relative to soluble iron catalyst addition. The research will focus on detecting the generation of three transient oxygen species in modified Fenton's reactions: hydroxyl radical, superoxide anion, and the hydroperoxide anion, through trace mineral and soluble iron-catalyzed Fenton's reactions. The importance of each oxygen species will be evaluated for DNAPL destruction and the treatment of sorbed contaminants. Finally, practical delivery and stoichiometry considerations will be evaluated. The research will provide definitive elucidation of mechanisms and integrate the results to provide more effective process design for the full-scale application of Fenton-like ISCO.

BENEFIT: Results of this research will provide a solid foundation for implementing more technically effective and cost-effective Fenton's ISCO process conditions to cleanup contaminated sites.

ACCOMPLISHMENTS: During FY 2003, progress was made on evaluating rates of hydrogen peroxide decomposition by soluble iron, naturally-occurring minerals, and natural soils and subsurface solids. The results demonstrate that three minerals, pyrolusite, birnessite, and ferrihydrite, rapidly decompose hydrogen peroxide. These results are significant because they isolate the soil fraction that controls hydrogen peroxide decomposition. Using reactant-specific probes, the generation of the hydroxyl radical, superoxide, and hydroperoxide anion were investigated. A series of experiments were also carried out to determine the naphthalene degradation kinetics to identify products under Fenton's conditions with only the generation of hydroxyl radicals. Fenton's reactions generating both hydroxyl radical and superoxide produced numerous peaks.

TRANSITION: Results will be transitioned via controlled large-scale pilot studies and controlled field studies where the delivery of hydrogen peroxide, the formation of transient oxygen species, NAPL destruction, and contaminant oxidation and reduction can be throughly monitored with mass balances on all of the contaminant carbon in the system. Such larger-scale transition research could be sponsored through ESTCP or similar programs to investigate the Fenton's process at meso- and/or full scale. If in situ Fenton's systems can be fully optimized, hydrogen peroxide requirements (the most expensive chemical in the Fenton's process) could be dramatically reduced, providing significantly lower costs for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Understanding of In Situ Chemical Oxidation (ISCO); CU-1289

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Hood, GeoSyntec Consultants, Guelph, Ontario, Canada

FY 2004 FUNDS: $137K

DESCRIPTION: The use of In Situ Chemical Oxidation (ISCO) treatment of chlorinated solvent source areas is rapidly increasing as the DoD and other stakeholders search for remedial approaches that reduce long-term operations and maintenance requirements. While ISCO is a promising technology for some chemicals, there remains significant data needs related to reaction kinetics for common DoD chemicals, the effects of natural oxidant demand on oxidant mobility and delivery under varying site conditions, and the effects of ISCO on long-term groundwater quality. This project will focus on developing a comprehensive approach to quantifying degradation kinetics during ISCO by permanganate and Fenton's reagent, applying this approach to a broad spectrum of common groundwater kinetics. Another aim of this project is developing a rigorous bench-scale experimental methodology to measure the rate and extent of the aquifer matrix natural oxidant demand (NOD) with permanganate and Fenton's reagent and developing a comprehensive conceptual model describing the role of NOD on oxidant mobility in the subsurface. The long-term impacts of ISCO will be researched by identifying significant secondary impacts of oxidant application on groundwater geochemistry and microbial activity at the field scale. Finally, the project team will develop an ISCO guidance document for chlorinated solvent remediation, in association with the other ISCO project teams selected under this Statement of Need (SON). The document will include specific guidance on technology applicability, protocols for effectively employing site-specific laboratory and pilot-scale treatability testing, design guidance for oxidant delivery systems, and approaches for effective technology performance monitoring and validation.

BENEFIT: This research is designed to significantly improve the current understanding of reaction mechanisms and kinetics for chemicals commonly found at DoD facilities and the behavior of permanganate and Fenton's reagent in the various geological and geochemical environments encountered at DoD sites. This fundamental knowledge, which will be distilled into a guidance document, will enable DoD site managers to make better decisions when dealing with chlorinated solvents.

ACCOMPLISHMENTS: Comprehensive literature reviews of reactivity studies for both permanganate and Fenton's reagent (including hydroxyl radical studies) were used to developed a database of rate constants to identify major data gaps in oxidant reactivity for common groundwater contaminants. These rate constants will also be used as part of the reactivity correlation analysis. Aquifer matrix samples from field sites were collected and preliminary NOD studies with permanganate were initiated to evaluate the reliability of the batch measurement protocol with respect to initial permanganate concentration, oxidant. An additional batch study evaluating the impact of soil drying on the measured oxidant demand was completed. Results indicated that air-drying significantly decreased the measured oxidant demand of three of the six soils samples, suggesting that the soil drying procedure is a critical component of the oxidant demand testing protocol.

TRANSITION: GeoSyntec and its co-development partners will transition the performance and applicability data for the ISCO technology to the federal and non-federal sectors through the publication of research articles, the distribution of videos and pamphlets, the presentation of test results at conferences, and the development of a project web page. GeoSyntec will also market the technology to non-federal defense contractor facilities to communicate its potential to reduce environmental liabilities.

PROJECT SUMMARY

PROJECT TITLE & ID: Reaction and Transport Processes Controlling In Situ Chemical Oxidation of DNAPLs; CU-1290

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Siegrist, Colorado School of Mines, Golden, CO

FY 2004 FUNDS: $231K

DESCRIPTION: Chemical oxidation has emerged as a promising treatment method for remediation of sites contaminated by chlorinated solvents and petrochemicals. Fundamental and applied laboratory research has elucidated many aspects of the reaction stoichiometry, degradation pathways, and kinetics for common organic chemicals in aqueous systems as well as the effects of temperature, pH, and matrix composition. Currently, there are serious gaps in the knowledge base regarding in situ chemical oxidation (ISCO) for dense nonaqueous phase liquids (DNAPLs). As a result, ISCO applications at DNAPL sites have been limited and those that have occurred have been plagued with uncertain or poor performance. In this project, proven methodologies involving apparatus of varying scales and complexities will be used to explore two common oxidants (peroxide and permanganate) and contrasting oxidant application methods (low to high dose concentrations and low to high delivery densities) to treat different DNAPL masses and distributions under conditions representative of a range of subsurface settings. The research will also address the potential adverse secondary effects of applications of ISCO as well as the appropriate coupling of ISCO with pre- and post-ISCO treatment operations.

BENEFIT: Completion of this project will yield a knowledge base for the future development of guidance on the principles and practices of ISCO so that it can be selected as a preferred remedy when appropriate and be implemented to reliably achieve a given performance objective.

ACCOMPLISHMENTS: The researchers completed experimentation the for the bench-scale kinetic and DNAPL degradation studies and the bench-scale studies of porous media effects on oxidation reactions. The team initiated experimentation and modeling for the upscaling reaction and transport experiments. The experimentation was begun for the experimental evaluation of coupling ISCO.

TRANSITION: Results of this work will produce decision aids that will be designed for future guidance regarding when and how to apply ISCO to cost-effectively remediate DNAPL at a given site, using ISCO either as a stand-alone method or by coupling it with a pre- or post-ISCO operation.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of In Situ Oxidation via the Elucidation of Key Mechanistic Processes Impacting Technology Maturation and Development of Effective Application Protocol; CU-1291

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Denise MacMillan, U.S. Army Corps of Engineers Engineer Research and Development Center, Vicksburg, MS

FY 2004 FUNDS: $208K

DESCRIPTION: This project focuses on the idea that soil constituents known to react with chemical oxidizers can dramatically change the biogeochemistry of soils. The application of chemical oxidizers within non-aqueous phase liquids (NAPLs) is a poorly developed area and there is little data available for use in developing near-field remediation models (primarily with reaction and sorptive mechanisms). The design options are poorly documented and their relative performance has not been evaluated and there are key safety issues that have not been properly addressed with regard to using chemical oxidizers within in situ chemical oxidation (ISCO) systems. The primary objective of this project is to provide basic scientific information on the impact of applying chemical oxidizers and their fate within soil matrices. Secondary objectives include: (1) better understand and define what soil constituents impact transport of primary oxidizers and then determine how chemical oxidizers impact soil systems; (2) provide a better understanding of oxidizer- pure NAPL interactions; (3) develop and/or refine appropriate reactive, sorptive kinetic models (non- transport); (4) evaluate results using actual soils containing trichloroethylene (TCE), 2,4,6-trinitrotoluene (TNT), and Phenols (two of each); and (5) provide a well-documented evaluation of design protocols, inclusive of key safety issues.

BENEFIT: Resulting information will be used to refine current design protocols. Definition of the performing mechanisms should lead to significant process optimization. Delineation of those soil constituents that have the greatest impact on oxidizer stability within soil matrices will be achieved. Evaluation of the potential impacts of oxidation processes on receiving soil systems will provide insight into post-treatment options. A database that can be used for later development of biotic/abiotic treatment techniques will be generated. The project will also develop key kinetic information (reaction and adsorption) and generate process design guidance.

ACCOMPLISHMENTS: Soil collection was completed and a second high organic content soil was collected to replace the original sample, which contained interfering sticks and other plant debris. The other soils were characterized for particle size, pH, metals, total organic carbon, and total heterotrophs. Decay rates were calculated. Effects of stabilizers for the initial soils were also evaluated. Laboratory results showed a correlation between ozone demand in soil and in equilibrated water, suggesting that groundwater ozone demand could potentially be used as a predictor of soil ozone demand. Such a screening tool would eliminate costly initial soil collection. Bacterial degradation was shown to contribute significantly to hydrogen peroxide decay in average soil.

TRANSITION: Peer-reviewed papers and technical presentations will be prepared on the following topics: oxidizer fate, soil condition post-ISCO application, NAPL remediation, modeling, and design issues. The project intends to transition through ESTCP. There is a plan to organize an Engineering Foundation Conference on Application of Chemical Oxidation for Soils Remediation, working with other organizations. The research team also provides the Corps of Engineers with in-house expertise on ISCO, enabling further transfer of results.

PROJECT SUMMARY

PROJECT TITLE & ID: Decision Support System to Evaluate Effectiveness and Cost of Source Zone Treatment; CU-1292

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Newell, Groundwater Services, Inc., Houston, TX

FY 2004 FUNDS: $17K

DESCRIPTION: The dense non-aqueous phase liquid (DNAPL) site paradigm developed has resulted in two competing site remediation approaches: (1) aggressive treatment and removal of DNAPLs and (2) long-term, low intensity containment with management of the DNAPL dissolution products. The project will develop an easy-to-use decision support system that will allow users to simulate the characteristics of a source zone, simulate the effects of various remediation alternatives, and estimate the resulting remediation costs/benefits and plume patterns over time. Specific objectives include (1) developing a new source evaluation methodology that will represent different types of DNAPL source; (2) generating a family of source concentration vs. time curves for each generic source-setting and for key site-specific input data; (3) developing a Source Remediation Cost and Performance Database; (4) applying this methodology to a 20-30 site source zone database; (5) generating a list of general rules regarding when and where various forms of intensive or partial site remediation are appropriate and cost-effective based on case study results and input from the expert panel; and (6) developing an easy-to-use Decision Support System.

BENEFIT: The Decision Support System will enable the groundwater community to: (1) apply the general rules derived from the detailed analysis of 20-30 sites to conduct a planning-level "Tier 1" evaluation of intensive source remediation strategies; (2) perform a more detailed "Tier 2" evaluation of the site by entering data, representing the source zone as a series of generic source-settings, using the software to visualize the change in the plume over time and evaluate the costs vs. benefits of source remediation; and (3) reference new research data in the form of a Source Zone Database, a Source Remediation Cost and Performance Database, and results from the source-setting analysis.

ACCOMPLISHMENTS: During FY 2003, the team completed the remediation database. The database provided a summary of remediation performance from literature studies and identified more than 50 sites for possible inclusion in the source zone database. The database was designed to compile site characteristics and multi-year concentration vs. time curves at sites where active remediation was implemented. The team also performed a detailed analysis of concentration vs. time patterns from 17 sites in the Lawrence-Livermore chlorinated solvent database. The team analyzed the monitored natural attenuation (MNA) sites to determine statistical trends. Finally, a framework for using a NAPL dissolution model to illustrate the effect that different source architecture has on source concentration vs. time curves was developed. A number of permutations of the framework to evaluate run times, grid size, and other modeling issues were run.

TRANSITION: The cost and predictive features will generate cost data and help users visualize the plume over time for various source treatment alternatives. The general rules and input from the review panel, will be presented in the form of a simple table or graphic, and a short tech-transfer bulletin will be developed for distribution via the internet. Information will also be transferred through peer-reviewed journal articles, HTML files for use as web page, downloadable Source Zone Database and results of the application of the methodology to these sites, downloadable Source Remediation Cost and Performance Database, downloadable Decision Support Software and User's Manual and information bulletins on commonly-used online groundwater groups and technology-transfer systems.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Assessment Tools for Evaluation of the Benefits of DNAPL Source Zone Treatment; CU-1293

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Linda Abriola, Tufts University, Medford, MA

FY 2004 FUNDS: $251K

DESCRIPTION: Despite its importance to the evaluation of alternative site remediation and management options, relatively little research has been conducted to assess the post-treatment distribution, mass transfer, and biotransformation of dense non-aqueous phase liquids (DNAPLs). This project is a multidisciplinary integration of laboratory, field, and modeling studies designed to provide a more comprehensive understanding of these issues and to develop tools and protocols for field monitoring and cost/benefit analyses. Various levels of treatment and remediation technologies/approaches will be investigated under heterogeneous subsurface conditions representative of known contamination sites. Application of the developed tools will be evaluated at selected DNAPL field sites.

BENEFIT: Results will provide DoD site managers with tools and protocols designed to assess the effectiveness and cost-benefit potential of DNAPL source zone treatments. Anticipated project deliverables include: (1) field sampling and monitoring protocols to quantify pre- and post-treatment mass fluxes; (2) biological probe technologies to assess chlororespiring activity in source zones; and (3) cost analysis tools designed to provide simplified and detailed cost estimates for competing technologies. These tools are intended primarily for implementation within a pre-treatment decision process, in which several source zone treatment technologies would be evaluated.

ACCOMPLISHMENTS: During FY 2003, a two-dimensional (2D) aquifer cell consisting of a source area and a plume area was designed and constructed for DNAPL recovery and mass flux studies. Preliminary NAPL release and source zone treatment experiments were conducted in a similar 2-D aquifer cell to evaluate the effects of source zone packing and remediation strategy on mass recovery, post-treatment distribution and effluent concentrations of trichloroethene (TCE). Preliminary bench-scale source zone treatment experiments were conducted using four surfactant-enhanced aquifer remediation (SEAR) strategies. Based on results from these preliminary experiments, the first of the tetrachloroethene (PCE) solubilization experiments was initiated. Experiments to assess dechlorination activity at different PCE concentrations were performed with four pure cultures. Experiments to assess dechlorination activity in the presence of PCE-DNAPL were also performed in reactor systems. A conceptual model that includes anaerobic reductive dechlorination, interspecies hydrogen transfer, electron acceptor competition, and inhibition of competitor species in the presence of PCE was developed to describe chlororespiration in a source zone. A set of Fortran codes based on geostatistical methods were developed to propagate the probability distribution of the mass flux (possible values and corresponding probabilities) through a planar transect of field measurements of concentration and hydraulic conductivity.

TRANSITION: To reach site managers involved in source zone remediation and regulatory officers responsible for overseeing and approving such remedial actions, transition programs will be developed in cooperation with the EPA. These may include monitoring and assessment at additional field sites, white paper(s) describing the implementation of the protocols, and workshop(s) involving regulatory officials at the state and national level, government agencies, and relevant industries.

PROJECT SUMMARY

PROJECT TITLE & ID: Mass Transfer from Entrapped DNAPL Sources Undergoing Remediation: Characterization Methods and Prediction Tools; CU-1294

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tissa Illangasekare, Colorado School of Mines, Golden, CO

FY 2004 FUNDS: $341K

DESCRIPTION: Non-aqueous phase liquids (NAPLs) exhibit complex flow and entrapment behavior in naturally heterogeneous subsurface systems. Risk analysis to determine the effectiveness of remediation has to be conducted using the spatial and temporal distribution of NAPL concentrations in the contaminant plume. The physical process that is fundamental to determine both the pre- and post-remediation status of the contaminant plume is the mass transfer that occurs from the entrapped NAPL sources. The focus of this project is to understand, quantify, and model the process of mass transfer from source zones where dense non-aqueous phase liquid (DNAPL) is distributed in complex configurations due to unstable behavior and natural geologic heterogeneity. A research study that involves batch and bench-scale experimentation, physical modeling in intermediate-scale laboratory soil tanks, and validation of the predictive modeling tools will be conducted. The research will aim to determine whether the existing site characterization techniques have the capability and refinement to determine the pre- and post-remediation distribution of NAPL mass within the entrapment zones (residual and pools) and whether the current understanding of mass transfer and mixing that occur within DNAPL source zones in heterogeneous subsurface formations is adequate to make predictions on how the dissolved contaminant plume behaves following remediation.

BENEFIT: The basic scientific knowledge gained in this research and the developed prediction tools and site characterization methods will help DoD to make decisions on managing sites and to conduct cost/benefit analyses on the selection and implementation of different treatment technologies. The processes that govern mass transfer from complexly distributed DNAPL after application of three common source zone removal/ destruction technologies will be characterized. The impact of properly selected source zone treatment technologies for long-term achievement of end-point DNAPL saturations will be acceptable downstream contaminant levels.

ACCOMPLISHMENTS: During FY 2003, process characterization was completed at the batch, column, and two-dimensional (2D) bench scale. Spill simulations were conducted in intermediate-scale test tanks to generate data to validate the modeling tools and evaluate up-scaling methodologies. Significant progress was made in developing decision tools and the up-scaling methods for natural and surfactant enhanced dissolution. The selection and characterization of test DNAPLs to be used in the experiments were completed. Batch testing to determine partitioning coefficients for surfactant-treated DNAPL was completed. The determination of the post-treatment partitioning coefficients for the other technologies was initiated.

The model kinetics for KB-1 degrading PCE have been determined. The column experiments were initiated to determine effective mass transfer coefficients in the vicinity of tetrachloroethene (PCE) sources. The abiotic mass transfer experiments with two-dimensional flow cell with pools were completed, and analysis using a MODFLOW and Reactive Transport Three-Dimensional (RT3D) based model was initiated.

The investigations of chemical oxidation were performed in collaboration with project CU-1290. Batch testing to determine pre- and post- treatment partitioning coefficients was completed. A series of experiments in an intermediate-scale tank was initiated to study the mass transfer, matrix diffusion, and partitioning tracer behavior during pre- and- post oxidation.
All experimental tasks dealing with surfactant enhanced dissolution in columns and 2D cells were completed. Models for mass transfer and partitioning tracer behavior were developed based on MODFLOW and RT3D.

Preliminary results of theoretical analysis conducted using the validated numerical model showed that the mass transfer coefficients could be up-scaled from the laboratory scale to the grid scale of the simulation model. A large tank experiment with a random heterogeneity was initiated and data generated in this test as well as future large tank tests will be used to evaluate the new up-scaling methodology. Preliminary analysis suggested that down gradient concentration and mass flux data can be used to determine entrapment architecture using inverse modeling tools (e.g., PEST).

TRANSITION: The team is directing another research project to improve the U.S. Army Groundwater Modeling System (GMS). The modeling tool developed in this work may be included in GMS.

PROJECT SUMMARY

PROJECT TITLE & ID: Impacts of DNAPL Source Zone Treatment: Experimental and Modeling Assessment of Benefits of Partial Source Removal; CU-1295

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. A. Lynn Wood, U.S. Environmental Protection Agency, Office of Research and Development, Ada, OK

FY 2004 FUNDS: $272K

DESCRIPTION: At the nearly 17,000 sites on DoD installations potentially requiring environmental cleanup, there is a need for innovative source-zone treatment technologies that offer cost-effective risk reduction. Unfortunately, there is currently no consensus in the academic, technical and regulatory communities on the ecological or environmental impacts of dense non-aqueous phase liquid (DNAPL) source-zone treatment. The cost of source-zone treatment is high, and the anticipated benefits need to be understood before significant resources are committed to source-zone removal. Since it is not economically practical to remove all DNAPL mass from most source zones, the focus of this project is on the likely benefits from partial DNAPL mass removal using some aggressive in situ technology (e.g., alcohol or surfactant flushing; steam flooding; air sparging; chemical oxidation). The primary objective is to develop a scientifically defensible approach for assessing the long-term environmental impacts (i.e., benefits) of DNAPL removal from source zones. The fundamental premise is that contaminant flux from the source, rather than contaminant concentration, should be used as the basis for evaluating the effectiveness of remediation. An integrated three-pronged approach, comprised of laboratory experiments, field observations and numerical simulations, will be used.

BENEFIT: This project will develop sufficient understanding of the linkage between source-zone remediation and its impacts on dissolved plume behavior to permit optimization of the remedial process by balancing mass removal with plume attenuation. The experimental data and modeling analyses will provide a basis for developing appropriate flux-based remediation endpoints at DNAPL sites and will help in the design of cost-effective remediation technologies. Thus, project results will facilitate more comprehensive risk assessments that include evaluation of benefits derived in terms of decreased adverse impacts on human and ecological receptors and will provide a scientific basis for developing regulatory and policy guidelines for DNAPL source-zone remediation.

ACCOMPLISHMENTS: During FY 2003, contaminant mass discharge from the DNAPL source area at Hill Air Force Base (AFB) Operable Unit 2 was measured before and after surfactant-enhanced remediation. Initial results showed a substantial reduction in mass discharge as a result of partial source removal. Additional flux measurements were planned. Flux monitoring wells were installed at the East Gate Disposal Yard Area 1 site, Ft. Lewis, Washington for thermal remediation. A dual domain modeling approach using an analytical solution to simulate DNAPL dissolution was developed. This approach provided a practical means of simulating three-dimensional (3D) DNAPL field remediation.

TRANSITION: Results will be presented at national and international professional meetings and published in peer-reviewed journals. The team will also publish project findings in technical magazines, such as Pollution Engineering, Ground Water Monitoring Review, and other trade journals. At the conclusion of the project, two additional documents will be prepared for general distribution: (1) a technical document summarizing the findings of the research, and made accessible on the internet and in CD-ROM format; and (2) an executive summary document, written for lay audiences interested in obtaining a grasp of the research findings and their implications in hazardous-waste site management.

PROJECT SUMMARY

PROJECT TITLE & ID: Identification of Metabolic Routes and Catabolic Enzymes Involved in Phytoremediation of the Nitro-Substituted Explosives TNT, RDX, and HMX; CU-1317

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jerald Schnoor, The University of Iowa, Iowa City, IA

FY 2004 FUNDS: $199K

DESCRIPTION: Manufacture of explosives and military operations as well as destruction of ammunition stocks have generated toxic wastes leading to contamination of soils and groundwater. Phytoremediation is an innovative technology capable of sustained prevention of migration of surface and near-surface soil contamination by energetic materials, which is applicable to large, potentially vegetated areas and directed to the long-term control of energetic materials. Although higher plants have been shown to take up energetic pollutants from groundwater and soil, little information is available about the fate of pollutants inside plant tissues. In the absence of further transformation and detoxification, metabolites will sooner or later return to the soil, resulting in a pollution transfer and a potential biohazard for the environment. The objective of this project is to explore the metabolic routes and the catabolic enzymes involved in the transformation and detoxification of the nitro-substituted explosives 2,4,6-trinitrotoluene (TNT), hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), and octahydro-1,3,5,7-tetranitro 1,3,5,7-tetrazocine (HMX) by poplar trees – a model plant for phytoremediation studies. A secondary objective will be to investigate the toxicity associated with nitro- substituted explosives and phyto- transformed metabolites, once taken up inside poplar tree tissues.

BENEFIT: Investigation of metabolic pathways, catabolic enzymes, and toxicity associated with the phytotransformation of energetic pollutants will contribute to a better understanding of the approaches needed to contain energetic contamination source zones on large vegetated areas over the long-term. Satisfactory results would lead to the application of practical phytoremediation strategies for the removal of RDX, HMX, and TNT by hybrid poplar trees.

ACCOMPLISHMENTS: Results from the biodegradation of TNT, RDX, and HMX using small plantlets (in vivo experiments) growing under hydroponic conditions showed that nitramines (i.e., RDX and HMX) were translocated preferentially to the leaves, while TNT and its reduced metabolites accumulated mainly in root tissues. Degradation experiments on RDX, HMX, and TNT using plant tissue cultures (in vitro experiments) showed that, in addition to a single uptake of explosives, plant tissues were able to significantly transform them. Additionally, tissue cultures were shown to significantly mineralize radiolabeled RDX and HMX into radiolabeled carbon dioxide. Although sterile tissue cultures were developed to observe the pure action of plants tissue, an endosymbiotic bacterium inside poplar tissues was detected and identified as a Methylobacterium sp. strain BJ001. The bacterium in pure culture was shown to metabolize toxic explosives. Metabolism of TNT and RDX by plant tissues was shown to generate primarily reduction derivatives, i.e., 4-amino-2,6-dinitrotoluene (ADNTs) and 2,4-diamino-6-nitrotoluene (DANTs) from TNT and the mononitroso derivative (MNX), formaldehyde (HCHO) and methanol (CH3OH) from RDX.

TRANSITION: This research will help to isolate the role of plants on energetic degradation. Besides the behavior of explosive pollutants inside plants specifically cultivated for phytoremediation purposes, the approach will allow the potential hazard associated with the existing vegetation naturally growing on nitro-substituted explosives-contaminated sites to be investigated. Finally, the study provides a general approach to investigate the relevance and the efficiency of any phytoremediation system. The project intends to select an actual training range for eventual design and demonstration of the process.

PROJECT SUMMARY

PROJECT TITLE & ID: Engineering Transgenic Plants for the Sustained Containment and In Situ Treatment of Energetic Materials; CU-1318

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stuart Strand, University of Washington, Seattle, WA

FY 2004 FUNDS: $204K

DESCRIPTION: Containment of explosives in sites such as training ranges that receive periodic inputs of energetic materials using existing technologies continues to be demanding and very expensive. While it may be feasible to prevent horizontal movement using physical barriers, vertical migration of the more mobile compounds such as hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine (HMX) is a matter of major concern. Phytoremediation is generating excitement as an economical and self-sustaining alternative for containment and cleanup of toxic compounds. Plants have been shown to promote uptake, degradation and sequestration of 2,4,6-trinitrotoluene (TNT), but the activities are low and RDX is generally only partially transformed with RDX residuals being bound to plant tissues. In addition, phytoremediation is limited by the phytotoxicity of TNT and other munitions pollutants. These limitations can be addressed by the use of genetic engineering, whereby genes that encode enzymes active against xenobiotic compounds are expressed in plants. The overall objective of this project is to engineer transgenic plants that can be used to contain and degrade energetic materials on testing and training ranges. Both fundamental and applied studies will be undertaken to express in plants genes for the transformation and degradation of explosives. Bacterial genes that detoxify RDX, dinitrotoluene (DNT) and TNT will be inserted and expressed in tobacco, as a model plant system, and in poplar, black locust, and aspen, trees that are well-suited for sustained remediation of testing and training ranges.

BENEFIT: Ultimately, the project intends to develop a toolbox of plants with unique abilities to take up, contain, and degrade compounds used in military explosives, especially TNT and RDX. These plants will be made available for trials on DoD testing and training ranges. Phytoremediation using these transgenics promises to provide a nonintrusive, inexpensive, self-sustaining, easily confined, and environmentally friendly method for preventing contamination of groundwater from munitions compounds used on training ranges.

ACCOMPLISHMENTS: During FY 2003, the team performed numerous transformations of the poplar clone with the three Agrobacterium tumefaciens strains, containing the nitroreductase gene (pNITRED3). The team transformed the poplar clone leaves with Agrobacterium rhizogenes strain R1601 containing the nitroreductase construct and developed hairy roots, which developed green shoots when transferred to light. To determine if poplar plantlets could be assayed in a similar way to the tobacco plants, poplar plantlets in liquid culture were grown. The team initiated construction on a binary vector for the overexpression of mammalian P450 3A4 and the poplar cytochrome P450 oxidoreductase. Arabidopsis plants were engineered to contain the cytochrome P450 genes, xplA, isolated from Rhodococcus rhodochrous strain 11Y, and the human P450, 3A4, which the team showed can degrade RDX in bacteria.

TRANSITION: Transition of results in three stages is planned, including greenhouse studies of tree metabolism in years three and four of this project, controlled field trials commencing after the completion of this project, then full-scale implementation on an active training range with monitoring.

PROJECT SUMMARY

PROJECT TITLE & ID: Genetic and Biochemical Basis for the Transformation of Energetic Materials (RDX, TNT, DNTs) by Plants; CU-1319

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jacqueline Shanks, Iowa State University, Ames, IA

FY 2004 FUNDS: $267K

DESCRIPTION: The energetic materials of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine (HMX), 2,4,6-trinitrotoluene (TNT), and dinitrotoluenes (DNTs) are possible sources of groundwater and surface soil (less than 1 foot) contamination at DoD testing and training sites. RDX, in particular, is more mobile than the other compounds in groundwater. Phytoremediation is an inexpensive, self-sustaining treatment technology that may be suitable for prevention of contamination. Plants have the capability of transforming TNT, while RDX is primarily taken up and accumulated as the parent compound. However, the practicality of phytoremediation is limited by the fact that these chemicals are phytotoxic to plants. In addition, the ability to develop plant-based remediation systems is restricted by insufficient understanding of how plants uptake and/or transform and metabolize these energetic materials. The overall goal of this project is to construct a genetic and biochemical knowledge base for the transformation pathways of energetic materials by exploiting the fact that these chemicals are phytotoxic (approximately 5 parts per million (ppm) for TNT and 20 ppm for RDX). Specifically, the project will (1) screen mutagenized populations of the model plant, *Arabidopsis thaliana*, to isolate mutants that are resistant to RDX, DNTs and TNT, due to under- or over-expression of individual genes, (2) use transcriptome and proteome analyses to identify mutants, and (3) use metabolite analyses to select final mutants and link gene to function.

BENEFIT: This project will provide a knowledge base in the genetics, pathway structure, and operation of metabolism of energetic materials. Studies will facilitate selection and/or natural breeding of beneficial plant species, metabolic engineering of transgenic plants for phytoremediation, environmental impact assessment of suspected energetic materials-contaminated media, and design of phytoremediation processes for the treatment of contaminated media.

ACCOMPLISHMENTS: During FY 2003, the generation of mutants for resistance to TNT was successful. The team discovered 8 T-Deoxyribonucleic Acid (DNA) mutant lines and 5 enhancer-trap (4X) mutants. Mass balances and kinetic studies for wild-type Arabidopsis were completed. Further information regarding this project can be found on the following website developed by the Principal Investigator (PI): http://www.iastate.edu/~ch_e/faculty/vita/web_page/Homeframe.html.

TRANSITION: This basic research project will provide genes, genetic markers, and metabolic information that will be disseminated to several different entities including academic researchers and government labs for further development of the phytoremediation technology. Information will be shared when appropriate with other principal investigators whose projects are further "downstream" in the technology development process. A website of results will be maintained. More traditional routes of dissemination such as presentations at conferences and publications in journals will also be followed.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimal Search Strategy for the Definition of a DNAPL Source; CU-1347

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Pinder, University of Vermont, Burlington, VT

FY 2004 FUNDS: $124K

DESCRIPTION: Locating a dense non-aqueous phase liquid (DNAPL) source is very difficult because of its filamentous nature and the fact that it is, in general, a rather small target. The goal of this research is to use measurements that are relatively easy to make, such as soil gas or groundwater concentrations, to provide guidance in finding the source. The overall concept is to identify, prior to a detailed site investigation, where to initially sample the subsurface to determine the DNAPL source characteristics and then to update the investigative strategy in the field as the investigation proceeds. The approach exploits the concept that DNAPL is indicated by the presence of a DNAPL species concentrations in excess of a specified value attributable to dissolution as described by formulae based upon Raoult's law. A computer-based search strategy that uses groundwater flow and transport modeling under uncertainty, a linear Kalman filter, and an optimization algorithm will assist the groundwater professional in defining the DNAPL source. The algorithm will indicate where, and if necessary when, to sample groundwater quality in order to define the location of the DNAPL containing area identified with the pre-specified concentration of the target compound. The computer-based search strategy is interactive and will provide information on the location and approximate shape of the source and the plume simultaneously and in real-time. The objective of this project is to develop, test and evaluate a computer-assisted analysis algorithm to identify the location and geometry of a DNAPL source.

BENEFIT: The deliverable in this research is a computer-based search strategy that can be used by groundwater professionals to obtain, at least cost, information regarding a DNAPL source geometry and its location. Improved DNAPL source zone delineation and characterization has the potential to significantly reduce the duration and costs of remedial efforts.

ACCOMPLISHMENTS: The team reviewed existing information, evaluating its utility in the context of their research goals, and modified and extended published concepts. In particular, the team focused on literature relevant to random fields such as one encounters in groundwater flow and transport, to flow and transport models, and to the theory of the Kalman filter. A mathematical statement of the problem was also completed. The team reviewed existing methodology, created a new theory, and combined the existing and new theory into a new formulation as represented by a set of equations.

TRANSITION: One or more professional short courses attended by agency personnel will be held to transfer the information/concepts and associated user-friendly software in a formal academic setting to include hands-on experience. An operations manuals describing the concepts and utilization of the software will be prepared. In addition, results will be published in referred professional journals.

PROJECT SUMMARY

PROJECT TITLE & ID: Using Advanced Analysis Approaches to Complete Long-Term Evaluations of Natural Attenuation Processes on the Remediation of Dissolved Chlorinated Solvent Contamination; CU-1348

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Doug Downey, Parsons Infrastructure and Technology Group, Inc., Denver, CO

FY 2004 FUNDS: $87K

DESCRIPTION: The in situ treatment/containment effects of natural attenuation processes have been specifically integrated into hundreds of selected groundwater remedies for chlorinated aliphatic hydrocarbon (CAH) plumes across DoD facilities, either as stand-alone monitored natural attenuation (MNA) remedies or as part of multi-component remedial designs. There is now a need to develop supplemental technical guidance that focuses on methods to quantitatively evaluate the long-term performance of MNA at achieving remedial objectives and numerical cleanup levels. The objective of this project is to identify and compile available alternate and/or advanced analysis approaches that may be applied to site-specific characterization and long-term monitoring data to more thoroughly evaluate the long-term efficacy of CAH natural attenuation processes. Monitoring data from several DoD sites where MNA is part of the core groundwater remedy for CAH contamination will be compiled and evaluated using a select number of the advanced data-analysis techniques to create a compendium of case studies on how these various analysis approaches could be reasonably implemented, at the discretion of the DoD environmental manager, to address the analysis topics that could be a part of long-term MNA performance evaluations. Emphasis will be placed on determining how best to define cause-and-effect relationships that influence time-of-remediation estimates. The supplemental technical guidance document will include details on potential data analysis techniques, additional monitoring requirement recommendations, and the case studies developed.

BENEFIT: This effort will produce a technical guidance document that will assist DoD environmental project managers in thoroughly understanding and being able to quantitatively document the predicted long-term sustainability and cost-effectiveness of relying upon natural attenuation processes to treat and/or contain dissolved CAHs. Potential advanced analysis approaches that may need to be completed in order to meaningfully incorporate site-specific CAH natural attenuation data into long-term remedial decision- making will be defined. Significant savings for the DoD are possible by identifying how to use state-of-the- art analysis approaches to determine which CAH natural attenuation processes could be expected to be sustained, if any, to achieve reasonable remedial endpoints.

ACCOMPLISHMENTS: During FY 2003, the team developed an electronic survey requesting input on MNA evaluation criteria, from both a technical and "political" standpoint. Approximately 40 surveys were distributed and approximately 20 surveys were completed by from environmental professionals, including regulatory personnel with an interest in MNA. A summary report of MNA evaluation needs was initiated. The team gathered MNA data from approximately 20 DoD sites and identified candidate case study sites. The development of simple statistical tools for evaluating CAH mass reduction and decay rates was initiated.

TRANSITION: The Final Report for this project will be written as a technical guidance document, specifically for DoD environmental project managers. Together, these efforts and the continued interest in this type of information by regulators should help to transition proof-of-principle supporting data to more DoD activities and private contractors.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Protocol for Assessment of Long-Term Sustainability of Monitored Natural Attenuation of Chlorinated Solvent Plumes; CU-1349

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Widdowson, Virginia Tech, Blacksburg, VA

FY 2004 FUNDS: $319K

DESCRIPTION: Under suitable conditions, monitored natural attenuation (MNA) can be an effective strategy for restoring aquifer systems contaminated with chlorinated solvents. A better understanding of factors controlling the long-term sustainability of natural attenuation is needed along with methods to characterize and assess the potential for sustained MNA. The following three objectives will be addressed: (1) develop integrated protocols to assess the long-term sustainability of biological and physical attenuation processes; (2) implement the protocols and develop methods for practical site analyses using software tools and computer models in conjunction with routine field tests and monitoring regimes; and (3) field-test the protocols and field methods on selected sites and evaluate effects of controllable and uncontrollable parameter uncertainty on remediation outcomes.

BENEFIT: The outcome of this project will be a practical methodology to quantitatively evaluate feasibility and long-term sustainability of natural attenuation at chlorinated solvent sites while reducing cost and controlling risk. Technical guidance and integrated protocols for assessment of biotic and abiotic natural attenuation processes at chloroethene contaminated sites will be prepared. At project end, DoD will have quantitative tools for predicting the time of remediation, the sustainability of natural attenuation processes within this timeframe, and the degree of uncertainty associated with such results.

ACCOMPLISHMENTS: Two expert panel meetings were completed to assist in the development of guidelines for site characterization and assessment of long-term MNA sustainability.

The first meeting focused on physical/chemical processes and the second on biological processes. The team tested the model Sequential Electron Acceptor Three-Dimensional (SEAM3D) Reductive Dechlorination Package at two sites to elucidate the relative contributions of reductive dechlorination and direct oxidation. A three-dimensional (3D) model was developed for the Plattsburg Air Force Base (AFB), FT-002 site. A groundwater flow model using MODFLOW also was completed and calibrated. A solute transport model using SEAM3D was completed and calibrated for petroleum hydrocarbon data. Several laboratory methods for total mass and biodegradable fraction of organic carbon were successfully tested and the question of mass and mass extraction was investigated using several techniques including weight-loss on ignition, differential thermal analysis and chemical extractions. Numerical experiments were conducted to develop a practical parametric model for DNAPL dissolution kinetics and field calibration protocols to assess long-term source depletion. This was performed using a high resolution 3D simulation of DNAPL infiltration and long-term dissolution simulation in exactly-defined heterogeneous media. A model was developed and field-scale mass transfer coefficients were quantified for several source zone geometries.

TRANSITION: Results will be presented at conferences and published in peer-reviewed journals. Following extensive peer review, the technical guidance document and assessment tools will be disseminated through DoD service groups, participating DoD partner agencies, and using Virginia Tech internet resources. Further validation at additional sites will be pursued. New software products and updates to the SEAM3D model will be distributed through various DoD agencies and licensed to the private sector through the DoD Groundwater Modeling System. A short course will be developed to train DoD personnel and regulators MNA protocols and use of the software, the revised of SEAM3D.

PROJECT SUMMARY

PROJECT TITLE & ID: Decreasing Toxic Metal Bioavailability with Novel Soil Amendment Strategies; CU-1350

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Philip Jardine, Oak Ridge National Laboratory, Oak Ridge, TN

FY 2004 FUNDS: $344K

DESCRIPTION: There are thousands of metal-contaminated sites on DoD lands that are awaiting possible cleanup and closure. At metal-contaminated sites where public access will not be restricted, the ingestion of contaminated soil by children is the exposure pathway that generally determines the required degree of site remediation. The overall objective of this project is to develop an improved understanding and predictive capability of the enhanced immobilization and decreased bioaccessibility of hazardous metals in soil as a result of novel chemical amendment strategies. Metals of interest will be those that drive risk-based remedial action at DoD facilities, namely arsenic, chromium, cadmium, and lead. The specific objectives of this investigation are to develop (1) an improved understanding of the rates and mechanisms of enhanced metal sequestration in soils that have been treated with various organic and inorganic amendment strategies, (2) remedial protocols that maximize toxic metal sequestration and minimize bioaccessibility for a wide range of soil types and mixed metal systems, (3) an improved predictive capability for evaluating sequestration and bioaccessibility of mixed toxic metal systems for various amendments and soil types, and (4) a spreadsheet-based computer model to determine optimum soil remediation strategies, testing programs, and costs to meet risk targets with a specific level of confidence.

BENEFIT: The experimental and numerical results from this research will provide knowledge and information in previously unexplored areas of enhanced toxic metal sequestration and decreased bioaccessibility in soils to support DoD's performance/risk assessment and decision-making process for site restoration. Since actual and relevant DoD soils from more than forty Army, Navy, and Air Force sites will be used, many installations will benefit directly from this research. This project will provide a practical and scientifically defensible tool to reduce remediation costs at thousands of other DoD sites nationwide. With the spreadsheet-based computer model, site managers and risk assessors will be able to make better estimates of baseline risk, to determine if additional testing is cost-justified, and to determine the optimum soil amendment regime to minimize cost.

ACCOMPLISHMENTS: In FY 2003, three phosphate sources (volcanaphos, rock phosphate, and triple superphosphate) were added to numerous lead (PB) contaminated DoD soils. The soils were aged at 30% water content and the Pb bioaccessiblity was assessed with time. DoD soils with high concentrations of Pb typically showed a decrease in lead bioaccessibility when treated with the various phosphate sources. Phosphate treated DoD soils also exhibited a significant decrease in cadmium (Cd) bioaccessibility in most cases. DoD soils with high arsenic (As) concentrations typically showed a decrease in As bioaccessibility when treated with the iron-oxide, hematite. Backscattering electron microscopy coupled with energy dispersive spectroscopy and Raman spectroscopy showed that Pb was associated with aluminosilicates as both metallic and divalent (adsorbed) states for the Travis Air Force Base (AFB) soils. These techniques also show chromium (Cr) associated with iron coated aluminosilicates. These results provided molecular level understanding of toxic metal bioaccessibility and the use of amendment strategies to decrease metal bioacessibility.

TRANSITION: Results of this research will be transitioned to DoD and EPA cleanup activities through both broad-based information transfer and site-specific technology transfer. Easy-to-use, validated, peer- reviewed models will be produced to estimate enhanced soil-metal sequestration and decreased bioaccessibility in a wide range of DoD soils. Results will be transferred to specific site cleanup activities through model

validation using contaminated soils at specific DoD sites. Results will be presented at conferences, made available on the internet, and published in peer-reviewed journals, which is essential to facilitate regulatory and community understanding and acceptance. Further validation of the results through some site-funded in vivo studies will be pursued.

PROJECT SUMMARY

PROJECT TITLE & ID: Soil Amendments to Reduce Bioavailability of Metals in Soils: Experimental Studies and Spectroscopic Verification; CU-1351

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. M. Katherine Banks, Purdue University, West Lafayette, IN

FY 2004 FUNDS: $150K

DESCRIPTION: Thousands of DoD sites require cleanup as a result of contaminated soil. Heavy metals are among the most common pollutants, particularly lead (Pb), cadmium (Cd), arsenic (As), and chromium (Cr). Pollution with these metals at DoD facilities can be extensive and complete removal is prohibitively expensive. The overall objective of this project is to significantly and measurably reduce the bioavailability and chemical mobility of As, Cr, Cd and Pb in contaminated soils through the addition of soil amendments that bind the metals in place. Specific objectives include the following: (1) Determine the impact of adding phosphorus, sulfur-based compounds, iron-rich composted organic matter, and limestone (individually and combined) on the aqueous solubility and extractability of contaminant metals; (2) Quantify the residual toxicity of amended, metal-contaminated soils using standard bioassays including earthworms, lettuce germination/emergence, nematodes, and soil microorganisms; (3) Measure the effects of soil amendments on plant uptake (both metal-sensitive and hyperaccumulating) of contaminant metals; and (4) Use spectroscopic and structural methods to study the local environment of metals and the solid-phases that bind them.

BENEFIT: This research will elucidate the efficacy of each soil amendment approach, the chemical mechanisms involved, and the potential of each as a long-term solution for metal-contaminated soils. Several soil amendments that have the capability to immobilize contaminant metals will be identified. Implementation of the results on DoD sites will begin during the field verification phase of this project. Prospective facilities will be contacted with the objective of treating soils on their sites with the selected amendments. Ideal sites will be those that have elevated concentrations to make them of regulatory interest, but soils with metal concentrations greater than 10,000 mg/kg could be problematic in applying enough amendments to control liability over the long term.

ACCOMPLISHMENTS: During FY 2003, Camp Edwards, West Point, and Point Mugu samples were analyzed for chemical and physical properties to determine their suitability for inclusion in this project. Additionally, all soils were pretreated and separated into size fractions which were analyzed to determine dominant mineralogy.

TRANSITION: Results will be presented at conferences and published in peer-reviewed journals. A general guidance document will be prepared to augment the final report, which will thoroughly discuss the implications of the data gathered in each phase relevant to the development and implementation of an amendment plan. The project team will also work with the private sector to develop a plan for commercialization of products. The project intends to transition to the ESTCP.

PROJECT SUMMARY

PROJECT TITLE & ID: Facilitated Immobilization of Heavy Metals in Soil by Manipulation with Plant Byproducts; CU-1352

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Teresa Fan, University of Louisville, Louisville, KY

FY 2003 COMPLETED PROJECT

DESCRIPTION: Soil organic matter (SOM) was expected to play a key role in in situ bioremediation of both inorganic and organic pollutants because it regulates pollutant transport and bioavailability and can be readily manipulated by organic amendments and/or plant growth. Lignosulfonates (LS) are well-suited for use as organic amendments in immobilizing metal ions in contaminated soils. They are relatively resistant to microbial degradation, interact readily with metal ions, are available at low cost, and appear to be "friendly" in terrestrial environments. However, the chemical mechanism(s) underlying LS functions in these applications were unclear. It was not known how LS aging or humification could be exploited for metal stabilization. This one-year proof-of-concept project explored the use of LS for metal sequestration at the bench-scale and addressed the following two questions: (1) Can LS amendment and subsequent humification help sequester heavy elements in soils? and (2) Can the chemical sequestration mechanism(s) be understood?

BENEFIT: Improved understanding of the fundamental mechanisms of metal ion-SOM interactions is vital to soil bioremediation since it is the organic portion of soil that is amenable to rapid, engineered manipulation by organisms or amendments such as LS to achieve desired long-term stability of the sequestered metals. Once the bench-scale work is complete, the tools developed will be readily applied to pilot- or field-scale studies, which can lead to mechanism-based choice of organic amendments and design of processes for superior long-term immobilization of pollutant metal ions.

ACCOMPLISHMENTS: Cadmium contaminated soils were obtained from the former McClellan Air Force Base (AFB) and processed for soil aging experiments. Aging of this soil with LS and other organic amendments was completed, and soil leachates are being collected periodically for analysis.

TRANSITION: If successful, this project will serve as a foundation for further laboratory and field studies to provide unprecedented mechanistic information regarding SOM binding of metals, thereby facilitating the use of metal sequestration processes with organic amendments such as LS. Follow-on work will be pursued to apply the acquired knowledge to pilot-scale field tests, in partnership with the AFB Conversion Agency at McClellan. Through such efforts, a new organic amendment-based technology for metal sequestration may be developed and ready for full-scale deployment.

PROJECT SUMMARY

PROJECT TITLE & ID: Fusion of Tomography Tests for DNAPL Source Zone Characterization: Technology Development and Validation; CU-1365

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Walter Illman, University of Iowa, Iowa City, IA

FY 2004 FUNDS: $269K

DESCRIPTION: Dense Nonaqueous Phase Liquids (DNAPL) are prevalent at a large number of sites throughout the world. Development of a cost-effective technology that provides detailed images of DNAPL distributions in the source zones is essential. The objectives of this project include: (1) develop algorithms that fuse different types of information using a stochastic approach to provide a cost-effective characterization, monitoring, and predictive technology for the DNAPL source zone; (2) conduct laboratory experiments to test and verify this technology; and (3) distribute the results of the research through a web-based virtual tomography laboratory to assist scientists, engineers, and managers in solving DNAPL contamination problems. This technology exploits recently developed hydraulic/pneumatic tomography and expands the concept to the development of a conservative and partitioning tracer tomography to image the subsurface and DNAPL distributions without extensive invasive sampling. The new technology uses a stochastic fusion of information methodology to assimilate results of hydraulic, conservative, and partitioning tracer tomography surveys to derive the best estimate of the DNAPL residual distribution and to quantify its uncertainty. The techniques will be tested and validated in both numerical experiments and a sandbox.

BENEFIT: This project will provide a new generation of technology that images the three-dimensional (3D) spatial distribution of hydraulic heterogeneity in the subsurface, enabling the improved characterization of DNAPL source zones as compared to existing technologies. Effective characterization is critical for efficient remediation and long-term monitoring. This new technology also provides the means for real-time monitoring and forecasting of the fate of DNAPLs during remediation. More importantly, it provides uncertainty estimates that can facilitate better decision making.

ACCOMPLISHMENTS: During FY 2003, the team developed algorithms for steady hydraulic tomography, developed a graphical user interface program for the hydraulic tomography, and investigated different ways to derive arrival time of transient pressure front during a hydraulic tomography. Fabrication of two sandboxes at the University of Iowa was initiated. Methods to extract cores from the sandbox were also designed, and fabrication of a constant head permeameter and apparatus for tracer testing of the extracted core was initiated. Work begun to refurbish the rapid sediment analyzer to obtain the grain size distribution of core samples.

TRANSITION: The stochastic fusion technology can be integrated with different characterization techniques in diverse geological conditions. It is also amenable to all stages of DNAPL source zone characterization including initial screening, site characterization, remediation, and long-term monitoring. The team intends to explore the possibility to include geophysical methods into the stochastic information fusion technology to enhance the imaging capabilities of subsurface contamination. Moreover, this research will be expanded to support field-scale characterization of DNAPL location and strength as a contaminant source in the vadose zone and in fractured rocks. A web-based virtual tomography laboratory will be created.

PROJECT SUMMARY

PROJECT TITLE & ID: Hydraulic Tomography and High-Resolution Slug Testing to Determine Hydraulic Conductivity Distributions; CU-1367

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Carl McElwee, University of Kansas, Lawrence, KS

FY 2004 FUNDS: $50K

DESCRIPTION: A considerable body of research has shown that the major control on the transport and fate of a pollutant as it moves through an aquifer is the spatial distribution of hydraulic conductivity. Although chemical and microbial processes clearly play important roles, their influence cannot fully be understood without a detailed knowledge of the subsurface variations in hydraulic conductivity at a site. Conventional hydraulic field techniques only provide information of a highly averaged nature or information restricted to the immediate vicinity of the test well. The objective of this project is to develop and improve field techniques for better definition of the three-dimensional (3D) spatial distribution of hydraulic conductivity by using hydraulic tomography coupled with high-resolution slug testing.

High-resolution slug testing allows the delineation of the vertical distribution of hydraulic conductivity near an observation well. This method will be combined with another innovative method for investigating the hydraulic conductivity distribution between wells, called hydraulic tomography. The phase and amplitude through space of an oscillating signal will be measured in order to estimate the hydraulic conductivity distribution of the material through which it has traveled. Preliminary work has shown that the phase and amplitude of the received signal can be measured over reasonable distances. The high-resolution slug testing results will be used as an initial condition and will provide conditioning for the tomographic inverse procedure to help with any nonuniqueness issues. Slug test data are most accurate near the tested well and should probably not be extrapolated blindly between wells. Together, slug testing and hydraulic tomography should be more powerful than either one used in isolation and should give the best opportunity to characterize the hydraulic conductivity in situ by a direct measure of water flow, as an alternative to indirect methods using geophysical techniques.

BENEFIT: This project will develop techniques with the ability to map three dimensional hydraulic conductivity distributions. The incorporation of a more realistic representation of the hydraulic conductivity distribution into a site model should lead to a more reliable risk assessment and remediation plan. Given the large number of sites of groundwater pollution, the impact/applicability of the results of this research is potentially great.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: With the advent of direct push technology (e.g., commercial Geoprobe system and the Army and Navy penetrometer Site Characterization and Analysis Pentrometer System [SCAPS] system), it may not be too difficult or expensive to perform this technique over an extended area that requires intense characterization for remediation. The equipment and data processing necessary to implement this technique will eventually be suitable for routine use. Although the initial work will be performed at a research site, it is expected that the technique will have general applicability and a military site could be chosen for demonstration of the technique.

PROJECT SUMMARY

PROJECT TITLE & ID: Abiotic Reductive Dechlorination of Tetrachloroethylene and Trichloroethylene in Anaerobic Environments; CU-1368

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Elizabeth Butler, University of Oklahoma, Norman, OK

FY 2004 FUNDS: $151K

DESCRIPTION: Due to the high cost and uneven performance of traditional remediation technologies, monitored natural attenuation is emerging as a new technology for groundwater remediation of pollutants. In anaerobic environments, tetrachloroethene (PCE) and trichloroethene (TCE) are susceptible to reductive dechlorination by microorganisms as well as purely abiotic reductive dechlorination by reduced minerals such as magnetite and iron sulfide. These mineral-mediated abiotic reactions result in PCE and TCE transformation by dichloroelimination, which forms reaction products distinct from microbial reductive dechlorination, which takes place by hydrogenolysis. The overall objective of this project is to develop and apply methods to quantify the rates of abiotic natural attenuation at sites contaminated with PCE and TCE. Specific research objectives include: (1) assess whether stable (i.e., non-radioactive) carbon (C) isotope fractionation can be used to distinguish between abiotic and biotic reductive dechlorination of TCE and PCE; (2) identify the geochemical conditions most strongly correlated with high rates of abiotic PCE and TCE reductive dechlorination in well-defined microcosm studies; and (3) validate and apply the findings at a series of DoD field sites contaminated with PCE or TCE. The following two approaches will be used to assess the rates and importance of abiotic reductive dechlorination: analysis of stable C isotope fractionation and analysis of PCE and TCE product distribution.

BENEFIT: This project will advance the state-of-the-science in natural attenuation by assessing the potential for abiotic natural attenuation of PCE and TCE under anaerobic conditions. Geochemical conditions under which abiotic reductive dechlorination is significant and the reductants responsible for dechlorination will be identified. Abiotic natural attenuation rates will be quantified and site-specific geochemical conditions, such as reactive mineral phases and terminal electron acceptors, will be correlated with rates of abiotic reductive dechlorination.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The transition to practice will begin by testing and validating the findings at four contaminated DoD sites. Peer review of research results will be a prerequisite for their further application. Therefore, results will be disseminated through publications in peer-reviewed journals and books, and by presentations at national conferences and SERDP symposia. To train the next generation of environmental practitioners in abiotic natural attenuation reactions, results will also be disseminated to undergraduate and graduate class activities at the University of Oklahoma.

PROJECT SUMMARY

PROJECT TITLE & ID: Sustainability of Long-Term Abiotic Attenuation of Chlorinated Ethenes; CU-1369

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Michelle Scherer, University of Iowa, Iowa City, IA

FY 2004 FUNDS: $235K

DESCRIPTION: The relative ineffectiveness and prohibitive costs of current approaches for remediating chlorinated solvent plumes has resulted in an increased reliance on natural biological, chemical, and physical processes to treat chlorinated solvents (i.e., natural attenuation). The role of biological processes in the fate of tetrachloroethene (PCE) and trichloroethene (TCE) has been studied in some detail, but little has been done to assess the importance of chemical (or abiotic) processes. Most naturally occurring reductants (i.e., reduced iron, sulfur, and organic matter) are thermodynamically capable of reducing PCE and TCE. Reduced iron, sulfur, and organic matter formed via both biological and chemical pathways have been shown to reduce a number of environmentally relevant contaminants and although there is some evidence that laboratory synthesized iron minerals can transform PCE and TCE, it is unclear whether this transformation process is sufficiently sustainable under field conditions to impact PCE and TCE groundwater plumes.

The objective of this project is to identify processes and mechanisms that could potentially account for the abiotic transformation of chlorinated ethenes in contaminated aquifers and to assess their likely importance under field conditions. The rate and extent of PCE and TCE transformation by abiotic reductants will be measured under flow conditions. The focus will be on abiotic reductants that have the potential to be continuously generated under field conditions via chemical dissolution or microbial activity (e.g., green rust, mackinawite, sorbed ferrous iron, reduced natural organic matter, and reduced supernatants formed in the presence of sulfate and iron reducing microbes). The sustainability of abiotic transformation of PCE and TCE will be assessed using a recirculating packed-bed reactor. The effect of water chemistry (e.g., pH, bicarbonate, sulfate, nitrate, oxygen, and presence of natural organic matter) and mineral aging on the rate and extent of PCE and TCE transformation also will be characterized.

BENEFIT: Direct outcomes from this project will include kinetic rate coefficients and product branching ratios that can be used to assess the likelihood of abiotic attenuation of PCE and TCE at DoD and DOE sites. To date, there are only limited rate coefficients available, and no study has addressed the sustainability of these pathways in natural systems.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The insight derived from these investigations will provide an improved basis for predicting the fate of chlorinated ethenes in anoxic soils, sediments, and aquifers and improving the design and implementation of remediation technologies based on abiotic transformations.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Contaminant Migration Potential through In-Place Sediment Caps; CU-1370

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Victor Magar, Battelle Memorial Institute, Columbus, OH

FY 2004 FUNDS: $25K

DESCRIPTION: Due to potentially negative impacts of sediment contaminants on aquatic environments and food resources, there is an increasing need to understand the fate and transport of contaminants in sediments and to identify, develop, and improve sediment management practices that reduce risks to human and environmental receptors. By isolating contaminated sediments, capping can effectively reduce exposure to contaminants and the possibility of contaminant transport into the food chain. However, because contaminants are left in place, caps generally require long-term monitoring and the risks of contaminant breakthrough or sediment resuspension persist. The scientific and engineering principles of capping may be improved through the development of a theoretical foundation that describes and validates the processes that retard vertical contaminant migration through caps. Many contaminated marine sediment sites reside in shallow, coastal areas that are often impacted by advective processes such as groundwater flow, tidal pumping, and wave pumping. These forces may contribute to the advective flux of contaminants through sediments and ultimately through a sediment cap.

The overall objective of this project is to enhance the scientific understanding of contaminant migration through sediment caps in areas with significant groundwater potential or tidal fluctuations. Specific objectives will be to examine contaminant mobility over time through an existing sediment cap at the U.S. Army Corps of Engineers (USACE)/EPA-operated Wyckoff/Eagle Harbor Superfund Site in Washington; quantify aqueous contaminant mobility and retardation in the laboratory; measure the influence of porewater flux via groundwater advection and tidal pumping; and evaluate the fundamental mechanisms that contribute to PAH sorption and retardation.

BENEFIT: This project will provide DoD and other federal agencies with improved tools for more cost-effective cap design and construction. These tools can be used to identify sites where sediment capping is appropriate, properly design sediment caps, select appropriate cap materials, and predict long-term cap performance and potential risks to human health and the environment. In addition, the results will have value for understanding the behavior of other hydrophobic contaminants (e.g., PCBs) and for contaminant behavior in natural and engineered systems.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: There is broad interest within DoD for the development and refinement of sediment remediation technologies and for credible methods to measure and predict the effectiveness of these technologies. The USACE and EPA partners have vested interests in the success of this work and are committed to transitioning the knowledge, methods, and information gained under this project throughout DoD and EPA. Knowledge from this program will be transitioned to the broader DoD community through technical reports, presentations, and professional publications. Each of the project team members is well experienced in reporting, public speaking, and publishing technical work.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrating Uncertainty Analysis in the Risk Characterization of In-Place Remedial Strategies; CU-1371

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Adriaens, University of Michigan, Ann Arbor, MI

FY 2004 FUNDS: $154K

DESCRIPTION: Every year, the Navy, U.S. Army Corps of Engineers (USACE) and ports dredge millions of cubic yards of sediments, some of which are contaminated with hazardous contaminants (polycyclic aromatic hydrocarbon [PAH]/polychlorinated biphenyl [PCB]/polychlorinated dibenzo-p-dioxins and dibenzofurans [PCDD-F]). Sediment remediation strategies are often developed on the basis of insufficient understanding of fundamental processes and site-specific empirical models, which have to be recreated at each site. High uncertainties can lead to estimates of risks that are too conservative, adding to remediation costs, or they can lead to insufficient protection, resulting in unanticipated impacts on human health and ecology. The objective of this project is to formulate pertinent relationships and decision criteria with reduced and quantified uncertainty in space and time that will allow better prediction of decision variables, system integrity and performance of in-place remedial strategies for PCB/PCDD/PAH-contaminated sediments. A combination of laboratory, flume and field experiments will be used to quantify the impacts of groundwater advection, gas ebullition, and microbial degradation on the physical and chemical stability of sediments and caps. Currently, these factors are less well understood than the more traditionally considered external forcings, such as current induced resuspension and, more recently, bioturbation. Two field sites have been selected, Pearl Harbor and Paleta Creek, on the basis of relevance to the DoD and opportunities to leverage past and ongoing projects at these sites. The experimental process is tightly integrated with uncertainty quantification and propagation to understand the effect of scaling from the laboratory to field and to provide guidance on the effects of uncertainty on the decision making frameworks for remediation.

BENEFIT: Through an understanding of basic scientific relationships and quantification of uncertainties, lessons learned from the field performance of in-place remedial strategies will be integrated and generalized in practical decision-making at new sites. Final results will be presented in a manner that is immediately transferable to existing decision support systems.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: To support the transitioning process, the project begins with an investigation of current field practices and ends with building conceptual models that can be immediately transferred to site investigations and contaminant fate and transport models. Collaboration with an environmental engineering company ensures that the first step of transitioning is built into the project, while their practical experience guides appropriate communication of results to the practitioner community.

PROJECT SUMMARY

PROJECT TITLE & ID: Anaerobic Biostimulation for the In Situ Precipitation and Long-Term Sequestration of Metal Sulfides; CU-1373

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mary DeFlaun, GeoSyntec Consultants, Princeton, NJ

FY 2004 FUNDS: $25K

DESCRIPTION: A recent report by the U.S. Army Corps of Engineers (USACE) cites 7,300 sites at 1,800 DoD installations with dissolved heavy metals contamination in groundwater. The objective of this project is to investigate an in situ strategy for precipitating arsenic (As) and potentially other heavy metals as stable metal sulfides and demonstrate long-term sequestration of these metals under changing geochemical conditions. Unlike organic contaminants, heavy metals cannot be destroyed. The appropriate application of any remediation technology for a heavy metal depends on a thorough understanding of the behavior of that metal, particularly its speciation and mobility in different environments. The fate of metals in the subsurface is controlled by many geochemical parameters, including pH, oxidationreduction (redox) potential, and salinity. These factors dictate the predominant forms (i.e., species) of metals in the subsurface and thus control the solubility and mobility of these metals.

In anaerobic environments, the mobility of heavy metals is often directly influenced by bacterial sulfate reduction, a process that is ubiquitous when sulfate and carbon substrates are available. Recent studies have shown that As-sulfide precipitates can be formed under the appropriate conditions by in situ biostimulation using ethanol and/or lactate as electron donors; however, there has been very limited research on the mineralogy and the stability of these precipitates under variable geochemical conditions although it has been suggested that these precipitates are relatively stable with low pH and under oxidizing conditions. Examining the mineralogy and establishing the rate of dissolution of these precipitates under aerobic conditions is the subject of this project. Results from anaerobic flow-through column studies will be used to make a go/no-go decision to perform a field-scale pilot test.

BENEFIT: Demonstration of a cost-effective, in situ, anaerobic biostimulation technology for the long-term sequestration of arsenic will aid DoD in complying with the recently lowered drinking water standards. In addition to arsenic, this technology may be applicable to a number of metals of concern at DoD and private industry sites.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: A successful field pilot that demonstrates the formation of arsenic sulfides will need to be followed by a longer-term demonstration to verify column-study results on the stability of these heavy-metal containing minerals. Two government agencies have expressed an interest in participating in the field demonstration of this technology, and it is likely that with the magnitude of the DoD problem ESTCP funding would be sought for a longer-term study of in situ heavy metals sequestration. This technology will be very attractive for both government and industry sites, including a large number of municipal landfills, if formation of a stable arsenic sulfide mineral can be established in situ.

PROJECT SUMMARY

PROJECT TITLE & ID: Monitored Natural Attenuation (MNA) and Augmented MNA of Arsenic in Groundwater; CU-1374

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Janet Hering, California Institute of Technology, Pasadena, CA

FY 2004 FUNDS: $50K

DESCRIPTION: Concern over groundwater contamination by arsenic (As) has recently intensified because of new information on As carcinogenicity and toxicity. The significantly more stringent As drinking water standard of 10 g/L is now in effect. There are numerous cases of As contamination in soil and groundwater at a large number of DoD facilities. Known sources of As contamination at DoD facilities include disposal of fly ash and past usage of arsenical pesticides. In addition, there are DoD facilities where naturally-occurring As in soils is released and mobilized into groundwater as a result of changes in subsurface redox conditions due to the aerobic metabolism of organics including petroleum hydrocarbons. Current treatment technologies, such as pump-and-treat, are costly and often ineffective. Although monitored natural attenuation (MNA) is often applied as a remedial action option for organics, it is less commonly applied for inorganics such as As. In contrast to MNA of organics, for which biodegradation is a principal mechanism for attenuation, the key MNA processes for inorganics include redox transformations, sorption, precipitation, and dilution.

The primary objective of this project is to understand, analyze, and evaluate the potential for MNA for use as a remediation option for As at DoD sites. Application and acceptance of MNA for As requires a thorough fundamental understanding of the processes affecting the fate and transport of As in the subsurface. The current paradigm for MNA in a general sense involves the assessment of the NA "footprint" (i.e., the evidence of the operational NA processes) at a given site. This involves proper conceptual model development that is then used to identify requisite site characterization needs. Acceptance of MNA as a remedial option has been gained for a site with As soil and groundwater contamination; however, routine, scientifically-defensible, and readily-acceptable application of MNA for As requires the development of a sound, peer-reviewed protocol.

BENEFIT: This project will develop a preliminary MNA protocol for As in soil and groundwater. Successful application of MNA for As will provide DoD with a viable, cost-effective remediation option for DoD As-contaminated sites, as does MNA of petroleum hydrocarbons and chlorinated solvents.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: A preliminary MNA protocol for As in soil and groundwater, developed in this project, is the principal element of the transition plan. The key collaborator in this effort is Dr. Robert Ford (EPA, Ada, OK) who is a lead EPA researcher on the development of a framework document for assessing the potential of MNA for inorganic contaminants (including As). The involvement of federal agencies is crucial to the eventual development and acceptance of a peer-reviewed full MNA protocol for As in groundwater. A follow-on ESTCP project applying the preliminary MNA protocol to a series of DoD As-contaminated sites with differing site characteristics (e.g., subsurface geology, hydrogeology, blogeochermistry, contaminant sources, co-contaminants) will greatly assist in technology transfer.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduced Iron Sulfide Systems for Removal of Heavy Metal Ions from Groundwater; CU-1375

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kim Hayes, University of Michigan, Ann Arbor, MI

FY 2004 FUNDS: $106K

DESCRIPTION: In situ abiotic/biotic permeable reactive barrier (PRB) systems offer great potential for the cost-effective removal of heavy metal ions from contaminated groundwater supplies. In these systems, reactive material is introduced into a "permeable wall" placed in the groundwater flow path to remove targeted contaminants. Of particular interest in this project is the use of particulate iron sulfide (FeS) in PRB applications. FeS has a high capacity for non-redox active metals such as Pb(II) and Cd(II) in which highly insoluble cadmium (Cd) or lead (Pb) sulfides form by favorably exchanging for Fe in FeS. For redox- active metals such as arsenic (As) and chromium (Cr), FeS serves as an effective reductant, converting oxidized forms of As(V) and Cr(VI) to more reduced forms of As(III) and Cr(III) and subsequently removing the metals by adsorption or formation of mixed-metal sulfide phases. Concerns remain, however, related to the longevity of materials, such as FeS, in PRBs and the impact of changing geochemical conditions (e.g., pH and redox) on long-term sequestration properties. A natural consequence of redox reactions and introduction of oxygenated water is the formation of more oxidized forms of FeS. In situ microbiological processes could provide a potentially attractive and cost-effective way to rejuvenate FeS for long-term use and reuse and to maintain reducing conditions.

The objective of this project is to evaluate the effectiveness of FeS for simultaneous sequestration of As and Cd in PRB applications. The effectiveness of reduced FeS as both a sorbent and reducing agent in PRB applications for long-term sequestration of heavy metal ions will be tested. FeS performance under various geochemical conditions will be investigated using batch reactor and column reactor systems. Mechanistic information on the metal removal mechanisms will be obtained by molecular-scale surface techniques, and microscopic tools. Various amendment configurations and emplacement methods will be tested. Rejuvenation of FeS using sulfate reducing microorganisms will also be examined. Finally, a reactive transport model will be developed using batch uptake and column breakthrough data.

BENEFIT: This research will lead to (1) a detailed understanding of the mechanisms of the reaction of As and Cd under changing geochemical conditions; (2) an assessment of the potential to rejuvenate FeS by biological means; (3) a determination of the feasibility of using various forms of FeS for PRB applications; (4) an understanding of the impact of metal removal mechanisms on transport properties in porous media; and (5) the development of a reactive transport model for design of PRB-FeS systems. The overall results will provide the tools needed to design and apply the FeS PRB media for effective long-term treatment of mixed-metal ion plumes at appropriate DoD sites.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: Information from this project will be disseminated to user groups via publications in the scientific and engineering literature and presentations to site managers and peers at national conferences. In the final year, a DoD site for applying the technology will be identified in consultation with DoD site managers and SERDP program officers. Following successful demonstration at the laboratory scale, a follow-on project through the ESTCP program will be proposed.

PROJECT SUMMARY

PROJECT TITLE & ID: Enhancement of In Situ Bioremediation of Energetic Compounds by Coupled Abiotic/Biotic Processes; CU-1376

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jim Szecsody, Pacific Northwest National Laboratory, Richland, WA

FY 2004 FUNDS: $295K

DESCRIPTION: When energetic compounds are released into the environment, natural and enhanced biodegradation occurs but is generally incomplete and toxic intermediates sometimes form. Fate and transport rates can also vary considerably among explosives and are dictated by differences in chemical structure. As such, energetic compounds and their intermediaries often persist in the subsurface, and with time, eventually contaminate groundwater. The objective of this project is to stimulate degradation of energetic compounds by abiotically creating an iron-reducing environment to promote initial abiotic transformations followed by subsequent microbial degradation of transformed energetic products. The application of coupled abiotic/biotic technology will be investigated using several energetic compounds that exhibit a wide range of subsurface reactivity. The technology reduces natural sediment iron oxides and structural iron in clay with a reductant, sodium dithionite. Coupled degradation of energetic compounds will be stimulated by the initial abiotic transformations followed by subsequent microbial degradation of transformed energetic products.

The biotic and abiotic mechanisms controlling the coupled abiotic/biotic degradation of energetics under iron-reducing conditions will be quantified through batch and column experiments and parallel modeling simulations. Microbial growth of explosives-degrading isolates and natural microbial consortiums will be quantified in a chemically reduced natural sediment under iron-reducing conditions. The impact of changes in microbial growth on mineralization rates also will be measured. The mineralization rate will be maximized by modifying the abiotic sediment reduction process. The relative importance of initial abiotic versus biotic transformation of energetic compounds on the final mineralization rate will be quantified using parallel experiments with live, killed, and bioaugmented microbial communities. The process will be scaled through aqueous flow experiments of energetic compounds in reactive porous media systems, and the influence of flow at these high sediment/water ratios on mineralization rates through simulations with field-relevant processes will be quantified.

BENEFIT: When used alone, bioremediation and abiotic treatments are only partially successful in transforming parent structures and sometimes leave recalcitrant reaction intermediates that are more toxic than the parent compounds. This project will quantify the biochemical reductive processes occurring in the redox barrier and determine the importance of these transformations on total mineralization rates. The coupled abiotic/biotic process has the potential to reduce the toxicity, mobility, and volume of recalcitrant energetic compounds in a variety of subsurface environments.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: Because the abiotic technology has been employed at several field sites, this experience will be used to design field-scale remediation scenarios for this coupled technology. Two-dimensional (2D) simulations will be conducted with reductant injection into heterogeneous porous media to determine configurations that would likely be successful in the field. Collectively, this study will provide the basis for upscaling this coupled abiotic/biotic technology for field-scale treatment of energetic compounds in the subsurface environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Biodegradation of Nitroaromatic Compounds by Stimulating Humic Substance- and Fe(III)-Reduction; CU-1377

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin Finneran, GeoSyntec Consultants, Boxborough, MA

FY 2004 FUNDS: $180K

DESCRIPTION: The DoD has identified nitroaromatic compounds as contaminants of concern at numerous locations including ammunition depots, production facilities, and live-fire training installations. Nitroaromatic and nitramine compounds such as trinitrotoluene (TNT), hexahydro-1,3,5tnnitro-1,3,5-triazine (RDX), and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) are explosives that are soluble at low concentrations and pose a threat to soil, sediment, and groundwater. Off-site migration of contaminated groundwater may prove to be a direct threat to human health and the environment. The technologies typically used for contaminated groundwater are inefficient for removing or detoxifying nitroaromatic- contaminated groundwater. The overall objective of this project is to investigate an in situ strategy for anaerobically degrading RDX by stimulating Fe(III)- and humics-reducing microorganisms in situ. Specific objectives include: (1) demonstrate that humic substances added to RDX-contaminated aquifer material will stimulate Fe(III) reduction and promote RDX reduction; (2) determine if humic substances (natural and synthetic) will transfer electrons directly to RDX; (3) quantify the rate of RDX reduction catalyzed by Fe(III) versus reduced humic substances; and (4) identify the dominant microbial community associated with humics and Fe(III) mediated RDX reduction.

BENEFIT: Humic substance mediated RDX bioremediation of nitroaromatic compounds is a simple, in situ alternative to bioremediation in anaerobic subsurface environments, aerobic bioremedation, pump-and-treat, and zero-valent iron. Regulatory acceptance for this technology is likely given that humic substances are natural compounds, Fe(III)- and humics-reducing microorganisms are ubiquitous, and all amendments are soluble. This technology may also be well-suited for co-mingled plumes, which are common at DoD sites.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: If successful, this technology can be applied to contaminated subsurface environments such as the Picatinny Arsenal in New Jersey or the Massachusetts Military Reservation in Massachusetts.

PROJECT SUMMARY

PROJECT TITLE & ID: Groundwater Chemistry and Microbial Ecology Effects on Explosives Biodegradation; CU-1378

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Fuller, Shaw Environmental and Infrastructure, Inc., Lawrenceville, NJ

FY 2004 FUNDS: $318K

DESCRIPTION: Military training activities have resulted in contamination of soil, sediment and groundwater with nitroaromatic (e.g., 2,4,6-trinitrotoluene [TNT], dinitrotoluene [DNT]) and nitramine (e.g., hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX], octahydro-1,3,5,7-tetranitro 1,3,5,7-tetrazocine [HMX]) explosive compounds. Although much information regarding the biological degradation of these contaminants has been published in recent years, little information is currently available relating how environmental conditions influence the composition and activity of the explosives-degrading microbial populations, how analysis of microbial communities can be used to predict the fate of explosives, and how site conditions can be manipulated to improve biodegradation activity. The objective of this project is to develop a better understanding of how environmental conditions affect the biotransformation and biodegradation of explosive compounds in groundwater and to examine how these variables affect the composition and functioning of the indigenous microbial communities with respect to explosive compound biodegradation. This project will employ molecular techniques to examine the microbial communities and activities associated with explosive compound biotransformation and biodegradation. The molecular microbiology data will be combined with analysis of the parent explosive compound and breakdown product concentrations. An analysis of the relationships between the microbial, chemical, and geochemical data will be performed under a variety of geochemical conditions to begin developing predictive tools and models for assessing the fate of explosives in the environment and their impact on environmental resources.

BENEFIT: The results will yield additional information into the microbial ecology of explosives transformation and degradation, facilitate the development of applicable field technologies for the complete degradation of nitroaromatic and nitramine explosives, and provide molecular tools for predicting and monitoring explosive biodegradation. This information will lead to improved predictability of the fate of explosives in the environment and a more rational selection of remedial alternatives including monitored natural attenuation, biostimulation, and bioaugmentation.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The results from this project are expected to be useful in the development of tools for assessing and predicting the success of explosive compound remediation efforts. Information can be used to provide improved procedures for monitoring both in situ and ex situ bioremediation of explosives-contaminated soil, sediment, and groundwater as well as being applicable to certain aspects of monitored natural attenuation of groundwater plumes.

APPENDIX B
Compliance Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Investigations of Improvements in Environmental Accountability, Safety, Process, and Training for New Technologies and Deconstruction Methodologies; CP-819

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Allan Roberts, National Environmental Education & Training Center, Indiana, PA

FY 2003 COMPLETED PROJECT

DESCRIPTION: New environmental technologies are often designed for efficacy with little consideration given to the safety of the technology to an operator, a maintenance worker or the community. As a result, significant time and energy is spent on re-engineering technologies to address health and safety issues. This project sought to assist in the development of maximal worker and environmentally protective processes and technologies. The goal was to produce efficient processes and technologies that are intrinsically safe and environmentally protective. The new processes and technologies were accompanied by upgraded information and training packages that foster safe, efficient implementation. The project focused on two specific areas, improvement of health and safety in new environmental technologies and development of more efficient processes in the dismantling and recycling of the Maritime Administration (MARAD) and U. S. Navy ships. Health and safety aspects included development of internet-based software that allow technology developers to incorporate safety in their designs and a series of field safety evaluations of environmental technology tests that result in the production of safety documents and an informational compact disk. The ship recycling project involved the cooperation of the Navy and private companies and investigated processes with a view towards improving them. Studies concerned actual cutting, recycling issues, improvements to planning, and development of more efficient training.

BENEFIT: The tools and data developed under this project, when coupled with existing "engineering design and management tools" will assist designers and technology implementers in evaluating and assessing health and safety issues in a focused, systematic way. It will lead to a consideration of worker and environmental safety and health implications associated with field (or production) use of innovative technology, and minimize the occurrence of health and safety concerns before and during end-user implementation. The ship dismantling project presents an opportunity to address the growing environmental problems posed by the MARAD and U.S. Navy inactive fleets, while creating jobs and spurring economic growth.

ACCOMPLISHMENTS: The core objective of the project, namely, the development and checking of an alternative profit/cost model was accomplished. The model provides a method to explicitly account for the impact of worker safety and health costs, environmental costs, and labor costs for different technologies on unit profit, within the general framework of cost and profit accounting for ship dismantling. The National Environmental Education and Training Center (NEETC) hosted the second Ship Recycling 2003 Conference, held April 2-4, 2003, in Washington, DC. More than 100 participants heard key congressional members pledge continued support for the disposal of the nation's fleet of retired and aging military vessels. NEETC evaluated 16 environmental technologies for the production of Technology Safety Data Sheets on each. TEXPERT and DOVE software programs were enhanced. NEETC also restructured proposals, deliverables and reporting.

TRANSITION: Transition consists of full implementation of an expert system made available on the internet or on diskette, demonstration at two technology development sites, and integration with a similar DOE program. Implementation of an outreach program via the internet is also underway.

PROJECT SUMMARY

PROJECT TITLE & ID: Distribution and Fate of Energetics on Department of Defense Test and Training Ranges; CP-1155

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Judith Pennington, U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS

FY 2004 FUNDS: $1,434K

DESCRIPTION: The primary objective of this project is to provide DoD with techniques to assess the potential for groundwater contamination from residues of high explosives (trinitrotoluene [TNT], pentaerythriol tetranitrate [PETN], hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX], and octahydro-1,3,5,7-tetranitro 1,3,5,7-tetrazocine [HMX]) at testing and training ranges. The effects of munitions type, range activities, and geographical and climatic conditions will be evaluated by sampling on ranges located at various sites across the country. The extent of contamination from higher order detonations will be determined by sampling impact craters on active ranges and conducting detonations on pristine snow. The extent of contamination from various degrees of low order detonations will be determined by creating low order detonations under controlled conditions where full recovery and analysis of contaminants is possible. Once the composition of post-blast residues is determined, environmental transport parameters will be developed and the distribution and concentration of the residues at ranges will be estimated. These data can be used to estimate site-specific source terms for use in risk assessment and fate and transport models.

BENEFIT: Project results will document activities at test and training ranges that have the potential to contaminate groundwater with residues of high explosives. Immediate benefits will include guidance for characterizing contamination, tools for anticipating the potential for environmental impacts, and tools for demonstrating responsible management of facilities to sustain their use for testing and training. These methods could result in substantial cost saving for site characterization and sustained use.

ACCOMPLISHMENTS: Since the inception of project CP-1155 in FY 2000, extensive range characterization sampling has been conducted to determine the extent and nature of explosives contamination resulting from various types of live-fire soldier training. To date, ranges at eighteen military installations in the U.S. and Canada have been sampled. Live-fire and blow-in-place testing has been conducted at three additional sites. Results demonstrate that characteristics of energetics contamination on ranges vary with the type of range activity and the specific munitions fired, and that the distribution of residues is extremely heterogeneous. Surface soil sampling techniques were developed to address the various sources of variability in range characterization data. Results of analyses of deposition from low- and high-order detonation tests conducted on snow and with witness plates provided an indication of the aerial extent and range in particle size of explosives residues. These results contributed to estimates of a source term associated with specific munitions. Specific results suggest that RDX is a significant contaminant of concern on live-fire ranges; TNT poses less threat to ground water than RDX; and propellant residues at firing points can be significant. Overall, conclusions are that high-order detonations, which constitute most of the explosions executed during training, generate undetectable to barely detectable, diffuse surface residuals. However, low-order detonations, the incidences of which are munitions-specific, are a potentially significant point source of environmental contamination. Furthermore, current practices for clearance of unexploded ordnance on ranges generate significant explosives contamination. The existing database of environmental fate parameters, which are essential for modeling contaminant transport and for defining the exposure potential for environmental risk assessments, was expanded to fill data gaps and provide dissolution data previously unavailable. Specific results indicate that initial release of energetics from compositions into soils tends to be locally very high, approaching temperature dependent saturation; soil adsorption will not significantly limit transport; explosives compositions dissolve more slowly than individual components; transformation rate depends on soil properties; TNT transforms readily to mono amino products in soils; TNT transport is limited by covalent

bonding of transformation products to soils; explosives residues are resistant to microbial degradation under conditions typical of ranges; and RDX is readily transported to groundwater. Range management practices recommended on the basis of the finding of this study include the following: tracking of duds and low-order detonations, removing/remediating duds and low-order detonations, tracking firing positions for characterization and remediation of propellant residues, improving blow-in-place procedures, and managing range use to minimized residues.

TRANSITION: Programs in place at all of the performing organizations will facilitate future widespread application of the procedures to determine the distribution and fate of energetics on DoD test and training ranges. Researchers at the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) Environmental Laboratory and Cold Regions Research Environmental Laboratory, as well as Sandia National Laboratory (SNL) are actively involved in developing procedures to assess the fate and transport of explosives from UXO. The research team has been advising the National Guard on the complex problems with explosives at the Massachusetts Military Reservation (MMR). A demonstration program under the ESTCP can validate guidance with on-site evaluation and modeling that are developed in the proposed project with which ERDC and SNL have prior experience.

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multi-Disciplinary Program; CP-1156

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. D. Bart Chadwick, Space and Naval Warfare Systems Command, San Diego, CA

FY 2004 FUNDS: $100K

DESCRIPTION: The objective of this work is to produce a method for estimating the impact of copper (Cu) and zinc (Zn) loading in estuarine environments. Cu and Zn species are incorporated in a hydrodynamic (physical) estuarine model that simulates the principal estuarine topography, tidally-driven currents, meteorology, and bottom characteristics. The model is used to compute water residence times in the estuary, the key physio-chemical variable against which all other rate-dependant processes are evaluated. Steady-state concentrations of metal species, including the steady-state concentrations of the "free" hydrated metal ion are computed from the hydrodynamic model, using known or experimentally measured input and sedimentation data for the estuary. The environmental impact of the steady-state concentrations of the toxic Cu and Zn species are evaluated in laboratory tests as well as field observations. The principal investigators from this project collaborate with two other SERDP projects on copper and zinc in estuarine systems (CP-1157 and CP-1158) and with other Navy projects working in this subject area. Unified sampling and analysis techniques have been developed by the three SERDP projects.

BENEFIT: This program benefits the DoD and broader environmental compliance as follows: (1) the methods and data developed are important to the DoD Uniform National Discharge Standards Program (UNDS), and (2) the information from this project will be transitioned to DoD environmental managers dealing with facilities and dredging compliance issues. The science resulting from this effort should provide a basis for DoD to work with the EPA in developing water quality criteria which account for the importance of metal species and complexation on toxicity. Finally, the scientific approach developed under this program can be used as a model for supporting development of reasonable criteria and standards for other metals and contaminants.

ACCOMPLISHMENTS: A numerical model has been developed to predict toxicity in Navy Harbors due to combined copper loading from all sources. Using an extensive field data program, the model has shown that the overall fate of copper in San Diego Bay is controlled by a balance between sources, flushing, and settling of the sediment with about 52% of the loading flushed out of the bay, and the remaining 48% transported to the sediment bed. The model also has been utilized to predict the "free ion", or toxic fraction of the copper. Results show that free copper concentrations in the main body of San Diego Bay were always below toxic levels. This finding is supported by extensive chemical and biological testing which shows no toxicity from ambient bay water. Bay-wide assessment of phytoplankton and bacteria has shown no alteration with respect to copper distributions. The modeling capability developed under this program provides an important tool for Navy environmental management, discharge assessment, and the implementation of site-specific water quality criteria in Navy harbors.

TRANSITION: Technology transfer will be through peer-reviewed journals, technical reports, and symposia. The products of this project may be transitioned to the ESTCP with proposed joint funding from the Navy.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Sources, and Bioavailability of Copper and Zinc in Department of Defense Impacted Harbors and Estuaries; CP-1158

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Martin Shafer, University of Wisconsin, Madison, WI

FY 2003 COMPLETED PROJECT

DESCRIPTION: The overall goal of this project was to advance the current understanding of the fate and impact of copper and zinc in harbors and estuaries. Specifically the project developed a quantitative understanding of the speciation, bioavailability and fate of important metal species transported to and found within DoD-impacted harbors. The objectives of this project were to: (1) apply and refine methods for speciation of copper (Cu) and zinc (Zn) in harbor and estuary waters; (2) assess the influences of environmental factors and processes on the speciation and fate of Cu and Zn; (3) interpret experimentally determined lability estimates of dominant metal-complexes in terms of time scales relevant to biological and physical processes; (4) compare modeled estimates of bioavailability of specific phases with biochemically determined exposure on experimental organisms; and (5) determine sources of Cu and Zn to harbors and estuaries using a multi-faceted approach of selective sampling, metal phase discrimination, and unique stable isotopic signatures to distinguish DoD sources of Cu and Zn to harbors and estuaries. By isolating functionally distinct metal "pools" within harbor systems, the lability (i.e., reactivity) of Cu and Zn can be characterized. The principal investigators from this project collaborated with SERDP researchers from two other SERDP projects studying copper and zinc in estuarine systems (CP-1156 and CP-1157) and with other Navy projects working in this subject area. Unified sampling and analysis techniques have been developed by the three SERDP projects.

BENEFIT: These findings allow the development of a method for the assessment of the potential of Cu and Zn to impact biological communities. The research substantiates that accounting for metal speciation will enable a more realistic estimation of acute and chronic risk for these metals, and these results will ultimately lead to development of scientifically-based water quality standards for copper and zinc in the aquatic environment. With these data, DoD can now evaluate their water quality compliance criteria and more accurately assess their potential impact on the harbor biological environment.

ACCOMPLISHMENTS: Studies found that the amount of copper uptake in algal cells directly correlates to the presence and quantity of Cu-binding complex ligands in the three impacted marine estuaries. The lability of Cu and Zn within "pools" or sinks in which trace metals can accumulate has been characterized using several complementary techniques, including electrochemical and resin-based methods. The bioavailability of Cu in specific pools was determined with three species of marine algae using both molecular and whole organism bioassay endpoints. Large gradients in metal speciation and metal-binding ligand were measured between and within systems; however, bioavailability studies indicate that Cu uptake into algal cells can be accurately predicted from levels of strong ligand, and therefore these results strongly support efforts to develop speciation-based water quality criteria.

TRANSITION: Data developed on Cu and Zn sources to and within the study systems will be used to construct or refine mass balances of metal loading. When coupled with information generated from this study on source specific metal availability, appropriate resources can be directed to controlling inputs with the greatest potential for ecosystem impact. Results from this work will be used in future permitting applications to determine whether stable-isotope technology should be applied to other impacted sites.

PROJECT SUMMARY

PROJECT TITLE & ID: A Predictive Capability for the Source Terms of Residual Energetic Materials from Burning and/or Detonation Activities; CP-1159

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Kolb, Aerodyne Research, Inc., Billerica, MA

FY 2003 COMPLETED PROJECT

DESCRIPTION: Detonation of energetic materials produces a wide range of air and surface pollutants, including carbon monoxide, nitrogen oxides, volatile organic compounds (VOCs), acid gases, and particulate matter (PM). The speciation and amounts of these emitted pollutants depend on the identity and amount of energetic material detonated, the detonation order, the detonation mode (air burst, surface detonation, buried detonation), and the munitions type (shell, mine, detonation charge, etc.). In order to determine whether U.S. military training or munitions disposal activities produce emissions that threaten air or ground water quality, reliable estimates of emission factors must be available for a representative fraction of the thousands of munitions types in the inventory. A variety of recent detonation experiments, including detonation chamber tests and open-air field detonations, have yielded increasingly rich data sets of measured gaseous and particulate emissions factors from a range of energetic materials deployed as both unconfined charges and standard munitions. These data were used under CP-1159 to guide the development of a detonation source characterization model (SCM) to be used to predict emissions across munitions classes and detonation modes. Specifically the SCM predicts the chemical and physical distribution of detonation products in the initial detonation fireball, calculates the amount, chemical influence, and deposition distribution of dirt entrained in the fireball, estimates the effects of afterburning as oxygen rich air is entrained into the hot rising plume of both gas phase and particulate emissions, and estimates the amount of shock ablated energetic material that escapes the fireball.

BENEFIT: The validated SCM can be used to extend emission factor predictions to unmeasured munitions types and to compute input data for traditional atmospheric dispersion/reaction models and soil/water transport/transformation models, which may then be used by environmental scientists and engineers to predict the impact of military training, weapons testing, or munitions disposal activities on military facilities and surrounding regions. The validated SCM allows the DoD to reliably estimate emission factors from representative munitions types and cost-effectively respond to regulatory concerns.

ACCOMPLISHMENTS: A detonation SCM was developed to predict potential air and ground water pollutants produced by exploding munitions and demolition charges. The SCM draws on new databases compiling munitions compositions and detonation products developed by collaborating scientists at the Army Environmental Center (AEC). The SCM has been validated with pollutant emission factor data obtained for a range of munitions and demolition charges obtained in an on-going series of detonation tests managed by AEC.

TRANSITION: The modeling capability developed by this project will be a public domain environmental assessment model. It will be reviewed for acceptance by applicable EPA offices involved in emissions modeling. Subject to EPA approval, it will be made available through the EPA regulatory support electronic bulletin board. The project results will be presented to potential users via journal articles, symposia, and technical reports. Potential users include all DoD, DOE, and EPA activities involved in open burning/open detonation activities.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of $PM_{2.5}$ Dust Emissions from Training/Testing Range Operations; CP-1190

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Veranth, University of Utah, Salt Lake City, UT

FY 2004 FUNDS: $193K

DESCRIPTION: This project is conducting field measurements and laboratory analyses of windblown dust and road dust resulting from troop operations at arid sites in the western U.S. The goal of this study is to provide installation-level environmental staff with scientifically validated information for developing emissions inventories, environmental assessments, and cost-effective dust control measures that are compatible with mission readiness. Source samples, laboratory analysis of these samples, development of advanced sample analysis techniques, theoretical modeling, and measurement of field emissions and receptor site particulates constitute the major components of this study. The study is based on two hypotheses developed from previous studies of dust emissions in arid climates. Only a small fraction of the dust that is initially suspended is actually transported long distances. Dust emissions from various sources potentially contain marker species that are present at higher concentrations than the regional background, and these markers can provide sensitive methods for quantifying the contribution of various source categories to the particulate collected at receptor sites. This experimental program tests these hypotheses with an integrated program of sampling dust at multiple locations and elevations during selected troop operations on unpaved roads or cross-country trails.

BENEFIT: Availability of an increased number of quantified dust species and of increased analytical sensitivity will benefit all current users of receptor modeling allowing more accurate apportionment to smaller sources. Improved apportionment will assist training ranges in developing cost-effective control strategies to meet environmental laws and to minimize citizen complaints from encroaching civilian communities.

ACCOMPLISHMENTS: The geographic and size variation of source dust from military training ranges and civilian sites in the western U.S. have been quantified following field sampling. The study indicated that local areas (e.g., Ft. Bliss West Fence compared to Ft. Bliss Range 40) have distinctive differences in the fugitive dust source profiles, but large area differences, defined by land ownership and management, are confounded since each area contains multiple source profiles. Findings have shown that the differences between PM_{10}, $PM_{2.5}$, and PM were small compared to the geographic variation, indicating that it is not necessary to analyze all size fractions individually with regard to interpreting source apportionment studies and designing future field sampling. Work on innovative methods to improve source profiles for source apportionment analysis has continued. A manuscript is in preparation on the results of an x-ray diffraction study to distinguish individual mineral species in soil dust filter samples. Thermal desorption/gas chromatography to identify organic markers in soil dust has shown promise and a technical report on feasibility of this technique is in preparation. Computational modeling of near-source dust deposition is in progress.

TRANSITION: The direct products of this study will include a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations and technical papers regarding field measurement, sample analysis, and data reduction methods.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterizing and Quantifying Local and Regional Particulate Matter Emissions from Department of Defense Installations; CP-1191

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Gillies, Desert Research Institute, Reno, NV

FY 2004 FUNDS: $75K

DESCRIPTION: Military activities on DoD installations in the southwest U.S. are potentially large contributors of wind-blown dust due to the presence of large expanses of fragile desert soils and testing and training activities. Particulate Matter (PM) emitted by these activities impacts vehicle performance, and threatens the health and safety of military personnel due to inhalation of PM and loss of visibility. This project proposes a systematic, empirically based research approach that combines environmental monitoring and field experimentation to quantify and characterize PM emissions from testing and training. To define sources (e.g., wind-blown dust, mobile sources, forest fires, industry, etc.) and their relative contributions to ambient PM levels, the Chemical Mass Balance (CMB) receptor model is used. The CMB estimates the relative contributions of different emission sources with known precision and accuracy to the loading of atmospheric PM. An emission factor database was developed using upwind-downwind monitoring methods to measure vehicle-generated emissions with fast-response instrumentation. Potential long-range transport of the emitted PM was assessed via field experiments. Potential visibility degradation off-post was determined with an intensive field measurement campaign.

BENEFIT: Specific benefits from the research include: (1) the development and demonstration of a methodology that will identify contributions of PM from specific on-post sources to the flux of PM exiting installation boundaries; (2) the development and demonstration of a methodology to define emission factors for military vehicles and an emission factor data base that can be used to estimate the contributions from different sources within an installation for various testing and training scenarios; (3) a model to convert the horizontal emission flux to vertical emission flux, allowing the emission inventory data to be utilized in dispersion models which estimate the long-distance transport potential of emitted PM; (4) the demonstration of a complimentary measurement procedure that utilizes the Testing Re-entrained Aerosol Kinetic Emissions from Roads (TRAKER) to determine horizontal emission fluxes and its effectiveness to map the emission potential of different surface types with great economy; and (5) characterization and quantification of the emissions from military activities. TRAKER can serve as an effective transfer standard to infer emissions from other wheeled vehicle types on unpaved roads.

ACCOMPLISHMENTS: The analysis of the air quality monitoring/CMB receptor model is complete, and the TRAKER approach has shown the ability to measure a road's potential to emit dust with reasonable repeatability. The major PM_{10} sources identified through CMB analysis of the chemical speciation data were fugitive dust, vegetative burning, ammonium sulfate (or bisulfate), ammonium nitrate, and sodium chloride. Contributions to regional levels ranged from a very modest 3 g/m^3 to a maximum of 20 g/m^3. The emission factors measured at Ft. Bliss showed a strong linear dependence on speed and vehicle weight. Emission factors (EF=grams of PM_{10} emitted per vehicle kilometer traveled) ranged from approximately 0.8g/km.hr for a light passenger car (~1,200 kg) to 48g/km.hr for large military vehicles (~18,000 kg). In comparison to emission estimates derived using U.S. EPA AP-42 methods, the measured emission factors indicate larger than estimated contributions for speeds generally >10-20 km/hr and for vehicle weights >3,000 kg. Interpretation of 2003 data from wind tunnel testing to assess surface disturbance effects on dust emissions and compare with initial disturbance data is ongoing. Image analysis to measure plant cover on the test plots is also ongoing, as this appears to be a major factor affecting emissions measured in 2003. Using the scattering measurements obtained with the DRI Integrating Sphere Integrating Nephelometer (ISIN), emission factors for scattering cross-section (ss, m^2/vkt) were developed. The dust emission factor algorithm that

simplifies the estimation of emissions as a function of vehicle weight and speed has been provided to SERDP project CP-1195, as well as a corresponding publication that details the development of emission factors. A methodology to estimate contributions from wind blown dust was produced and should prove useful for integration into the geographic information system (GIS)-based dust emission model.

TRANSITION: The acquired information can be transitioned to U.S. Army's Integrated Training and Management (ITAM) personnel and other installation environmental personnel who may need to deal with certain aspects of the dust and PM emission problem.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a GIS-Based Complex Terrain Model for Atmospheric Dust Dispersion; CP-1195

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. K. Jerry Allwine, Pacific Northwest National Laboratory, Richland, WA

FY 2004 FUNDS: $80K

DESCRIPTION: The objective of this project is to develop a fully tested and documented atmospheric dust dispersion modeling system for use by military staff to assess training/testing range contributions to local and regional air quality, to help manage dust-generating activities, and to help develop dust mitigation strategies. The dust dispersion modeling system must be robust, state-of-the-art, user-friendly, and most importantly, meet the needs of the staff responsible for addressing air quality issues from activities at military training/testing ranges.

This project characterizes dust emissions from range training/testing activities by (1) analyzing existing dust characterization data, (2) conducting additional field studies, and (3) developing a geographic information system (GIS)-based complex-terrain atmospheric dispersion model. This modeling system has several uses: (1) near real-time tracking of dust movement given real-time meteorological data and dust generation information, (2) performing air quality assessments, and (3) planning and evaluating training operations and dust control measures under various meteorological scenarios. A primary focus is to develop dust emission factors for range activities and incorporate the dust emission formulations into a U.S. EPA approved air quality model. The GIS-based air quality model will be compatible with available military land management and operational models and will incorporate the effects of complex terrain on dispersion.

BENEFIT: The completed modeling system will allow military personnel to specify training/testing activities using a GIS interface, run the atmospheric dispersion model, and then graphically view the dust impacts using a GIS. The model will also have the capability to provide real-time dust dispersion for those sites maintaining real-time weather measurement data. This capability will allow graphic, GIS-based representation of current and projected PM transport and concentration that will enable military staff to modify activities or locations to minimize health and environmental impacts of airborne dust and/or obscurants.

ACCOMPLISHMENTS: Accomplishments to date include: (1) an improved user interface, allowing the user more flexibility to build and save activity scenarios, specify and view various outputs, and set up modeling domains; (2) development of a meteorological module allowing meteorological data of various formats to be used; (3) formulation and testing of a wind-blown dust module as well as evaluation of the module using field data; (4) comparison of DUSTRAN results with some data from FORSCOM field studies at National Training Center (NTC); (5) ongoing rigorous operational testing of DUSTRAN, leading to code fixes and improvements; and (6) ongoing detailed documentation of the modeling system.

TRANSITION: The product (dispersion model and dust characterization techniques) will be transferred to military land managers and operational leaders for use during testing and training exercises and operation in order to reduce the generation of dust. The end product will include a field deployable time-tagged particle sampler and a documented measurement method for rapid, cost-effective assessment and mapping of roadway dust generation with high spatial resolution. With the emphasis on user needs and user input during the development of the model, transition to installation operation and use of the model should be greatly facilitated.

PROJECT SUMMARY

PROJECT TITLE & ID: A Field Program to Identify TRI Chemicals and Determine Emission Factors from Department of Defense Munitions; CP-1197

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Chester Spicer, Battelle Memorial Institute, Columbus, OH

FY 2004 FUNDS: $83K

DESCRIPTION: Military ranges are under increasing public scrutiny with respect to potential environmental hazards to nearby communities. A group of potential hazards includes toxic emissions from use of munitions during training and testing activities. The Emergency Planning and Community Right-to-Know Act (EPCRA) require industry and government agencies to report emissions of chemicals listed on the Toxic Release Inventory (TRI). DoD facilities, specifically testing and training ranges, need reliable air emissions data for TRI chemicals from munitions activities to meet this requirement.

The proposed program is designed to work closely with DoD services to (1) identify important munitions activities and sites, (2) use existing data and chemical principles to develop a list of target TRI chemicals that will be measured in the field, (3) recommend and deploy innovative state-of-the-art field monitoring technologies, and (4) collect real world data on munitions emissions for important munitions activities under a range of actual field conditions at field sites. These data will advance the state of knowledge of the nature and quantities of emissions from munitions activities and will help DoD meet its EPCRA reporting requirements by providing more accurate estimates. In addition, the accurate characterization of emissions from these activities will assist DoD in setting priorities for emissions reduction strategies.

BENEFIT: The goals of this project are to develop and validate a methodology for measuring TRI chemicals emitted by munitions used on training and testing ranges, to characterize the performance of the methodology under actual field conditions, and to develop emission factors for TRI chemicals for a set of priority munitions items. The emission factors will be used to evaluate exposure levels by persons operating these equipment or may be near munition explosions under testing and training conditions.

ACCOMPLISHMENTS: Researchers conducted two types of field campaigns. One is quantifying TRI emissions from the point of weapons discharge, and the other is measuring emissions from the detonation of munitions on impact. One of the objectives of the Point of Discharge (POD) study was to compare the project's measurement methods with accepted standard methods of the EPA and National Institute for Occupational Safety and Health, which often involve collecting large sample volumes over several minutes. Because the ultimate objective of the project was to quantify emissions in uncontrolled outdoor situations, where only a few seconds may be available for sampling, researchers selected and developed several fast-response, high sensitivity real-time measurement approaches. Results from comparison data of four chemicals (total carbon, formaldehyde, benzene, and copper) showed solid agreement between project methods and standard methods, providing credibility for the novel methods used for the Point of Impact (POI) studies. The POI tests required measurements of the concentrations of numerous chemicals in a relatively small, moving cloud of emissions, and either accurate measurements of a stable tracer chemical that was distributed in the cloud in the same manner as the target chemicals, or accurate estimates of the volume of the emissions cloud at the time of sampling. Since these tests were performed outdoors on a test range, where variable meteorology is a factor, a considerable effort during this project has been focused in on understanding the behavior of an emissions cloud following the detonation of an ordnance item, and devising a strategy that would provide the greatest chance of success for measuring TRI chemicals in that cloud with sufficient sensitivity to calculate emissions factors, and for measuring the volume of the cloud. The data from the POI campaign are currently being reduced. However, based on the field assessment of test success using pre-determined criteria, overall, 25 of the 35 munitions tests were judged to have been successful. Of the

unsuccessful tests, seven were due to the emissions cloud missing the sampling towers and three were caused by duds or incomplete detonations.

TRANSITION: There is a broad interest within DoD in developing a credible method to measure the emission factors that are used to estimate annual emissions, and in applying the method to measure emission factors from significant munitions activities. This will allow the military to address the potential hazards to military personnel and possibly drive the need for new environmentally compliant munitions.

PROJECT SUMMARY

PROJECT TITLE & ID: Measurement and Modeling of Energetic Material Mass Transfer to Pore Water; CP-1227

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan, Sandia National Laboratory, Albuquerque, NM

FY 2004 FUNDS: $100K

DESCRIPTION: Ordnance detonation during military testing and training operations leaves un-reacted energetic materials on and in near-surface soils. Transport of these energetic materials in soils is initiated by a mass transfer process to soil pore water. This project analyzed the mass transfer process using laboratory measurement and numerical simulation to produce an energetic material source release function linked to weather cycles. This effort involved two phases of experimentation and model development. Phase I consisted of an initial series of experiments designed to determine the critical parameters affecting the mass transfer of energetic materials to pore water and derive a mathematical function that incorporates the most significant factors. Phase II evaluated in greater detail the factors that have the greatest impact in the mass transfer process and actual post-blast residue in soil obtained from test or training ranges. Mass transfer rate data were collected in an unsaturated or saturated column test apparatus allowing variation in parameters representative of environmental condition in near surface soils. Actual range soil and post-blast residue were used to assess the accuracy of the mass transfer function.

BENEFIT: The inclusion of an energetic material source release function into a soil solute transport simulation code will create a new predictive ability to assess the migration potential of energetic materials left by military testing and training operations. This study supports range managers and allows improved decisions on management of this challenging problem.

ACCOMPLISHMENTS: The mass transfer process was evaluated using a column effluent apparatus. Column tests evaluated the impact of temperature, constant and dynamic water flux and porous media saturation, energetic material mass & particle size, and actual low order detonation debris. Test results have shown predominantly high effluent concentrations followed by a mass depletion stage where effluent concentrations decline until the solid phase mass is exhausted. The mass transfer relationship was modeled in a source release function using a mass transfer coefficient (k) and solid phase interfacial area (Ai) as principal parameters, which provided excellent representation of the experimental data. Future work will explore the interfacial area aspect with energetic material of various size fractions and the comparative results of actual low order detonation debris.

TRANSITION: Modelers can use this source release function as part of a solute transport simulation code to predict the fate and transport of energetic material in soil pore water. In addition, this work can be extended to evaluate groundwater impact and range management strategies by implementation through the Army Environmental Center (AEC).

PROJECT SUMMARY

PROJECT TITLE & ID: The Development of Spatially-Based Emission Factors from Real-Time Measurements of Gaseous Pollutants Using Cermet Sensors; CP-1243

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Natalia Meshkov, Argonne National Laboratory, Argonne, IL

FY 2004 FUNDS: $100K

DESCRIPTION: The DoD needs to identify and characterize emissions of trace air toxic compounds, especially persistent organic pollutants, from operations and activities at its facilities. This information is used to estimate emission factors used in environmental risk assessments. Currently, ambient air toxic concentration data for most urban air toxics (UATs) and mobile source air toxics (MSATs) are not available. This project aims to (1) develop miniature sensors and portable sensor arrays capable of rapidly detecting and characterizing trace air toxic compounds in near-real time, (2) integrate pollutant data into spatial and temporal emission profile models correlated with specific DoD activities, and (3) produce high quality emission factors for targeted pollutants released during various activities. Cermet (ceramic-metallic) electrocatalytic "smart" microsensors that monitor emissions in near-real time will be used. Cermet sensors are capable of operating over a wide temperature range (approximately -40 °C to 500 °C). Voltammetric analytical techniques employed by sensor operation allow for both a wide variety of gaseous constituents and a wide range of analyte concentrations to be detected, from parts per billion to percent levels. Advanced pattern recognition techniques are used to resolve composite signals from a mixture of gases into individual components. TiO_2 photocatalytic properties are used to develop new microsensors that complement voltammetric devices. By combining existing and experimental microsensor technologies, more capable and comprehensive microsensor arrays for selected emission constituents are developed. The new microsensor arrays are used to efficiently produce improved emission characterization profiles associated with DoD activities and to estimate and validate emission factors.

BENEFIT: The project provides DoD new sensing systems for detecting and characterizing trace air toxic compounds. These systems are portable, small, and inexpensive. Operating from a laptop computer, these systems can provide near-real-time analysis and feedback. UATs, MSATs and a spatial profile of air pollutants will be provided. The information gained from this project will advance the efforts to control pollutants and model the fate and transformation of pollutants.

ACCOMPLISHMENTS: New voltammetric devices were fabricated, and thick-film fabrication techniques, suitable for nano-particle film production, were developed. Lab tests were conducted with two types of electrochemical sensors on target gases acetaldehyde, acrolein, butadiene, and benzene, as well as air and nitrogen. The yttrium-stabilized zirconium (YSZ) and tungsten bismuth oxide (WBO) sensors showed distinctive responses to the different gases when tested at gas concentrations of about 1000 parts per million (ppm) in air. The run-to-run test results were smooth and reproducible. The YSZ sensor was also used to test the sensor response to different gas concentrations from 10 ppm to 1,000 ppm for acrolein and butadiene. Results suggest that it is possible to distinguish concentrations as well as compound type.

TRANSITION: Results from this project will enable the identification and characterization of the emissions of trace air toxic compounds produced from activities at DoD operations. Actual data from the research could be of direct interest to DoD facilities and the EPA since future regulations will be based upon the results of this research effort.

PROJECT SUMMARY

PROJECT TITLE & ID: Harmful Algae, Bacteria, and Fauna Transported by Department of Defense Vessels; CP-1244

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. JoAnn Burkholder, North Carolina State University, Raleigh, NC

FY 2004 FUNDS: $75K

DESCRIPTION: Ballast water is thought to represent the primary vector of marine non-indigenous introductions into the U.S. and elsewhere. There is concern that existing and proposed regulatory measures designed to control such introductions could translate into severe restriction for DoD vessels, unless this aspect of ship operations is more fully characterized and managed. The main goal of the research is to identify and quantify harmful or non-indigenous species of algae, bacteria, and microfauna transported via ballast water on representative vessels of the Military Sealift Command operating from the U.S. Atlantic and Pacific Coasts. Relationships between community abundance or diversity and variables such as origin, ballast tank architecture or management practices are being assessed. In addition, selected harmful species that are detected during these evaluations are being exposed to an experimental heat regimen to assess the potential of waste engine heat as means of treatment.

BENEFIT: Results of this study will fill a critical data gap, providing information on the abundance and diversity of aquatic species found in ballast waters from DoD vessels. The characterization of communities in the ballast water of DoD vessels, including 'harmful species,' together with bench-scale heat treatment experiments will assist the DoD in determining the measures necessary to reduce the risk of non-indigenous introductions to U.S. harbors and estuaries by ballast water. This project is coordinating these research efforts with CP-1245.

ACCOMPLISHMENTS: Sixteen vessels have been sampled to date, 10 at the San Diego Naval Station and 6 at the Norfolk Naval Station. Phytoplankton taxa identification and enumeration assessments have been completed for 13 of the 16 vessels sampled thus far. Identifications to species have been achieved in most cases, and assignment to major phytoplankton taxonomic groupings has been made in all cases. The methodology has now been developed for molecular bacterial screening of ballast water samples. Approximately 20 species have responded to enrichment and have been isolated in culture. In addition, selected harmful species that were detected during these evaluations are being exposed to an experimental heat regimen to assess the potential of waste engine heat as a means of treatment. As an example of this experimentation, researchers examined thermal tolerance of the dinoflagellate *Prorocentrum triestinium* cultured from ballast water samples, and found a positive correlation between varying temperature/duration of heat exposure and species mortality. A relational database is being developed for data organization, storage, and export for statistical analyses and for use in risk assessments. The database is being linked to a taxonomic image library and is designed to provide data for GIS mapping for several of the vessels that provided adequate data coverage and will be instrumental in helping to describe patterns in abundance and diversity at the end of the study.

TRANSITION: Results from this project will support the activities of the Unified National Discharge Standards (UNDS) program, which will analyze discharges from DoD vessels and develop performance standards for pollution control devices employed to treat these discharges. Information on the abundance and types of organisms found in ballast water and hull fouling will guide the formulation of scientifically-defensible treatment standards under the UNDS program and the development of effective pollution control devices.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Aquatic Non-Indigenous Species for Department of Defense Vessels; CP-1245

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Holm, Naval Surface Warfare Center, Carderock Division, West Bethesda, MD

FY 2004 FUNDS: $155K

DESCRIPTION: In order to develop a better understanding of the role DoD operations may play in the introduction of invasive aquatic species, researchers are quantifying the abundance and diversity of organisms populating the ballast tanks and hulls of DoD vessels operating on the Atlantic and Pacific coasts and relating these finding to operational and maintenance histories and management practices. The study is focused on the Norfolk and San Diego Naval Stations, and the vessels sampled include oilers and cargo vessels operated by or for the Military Sealift Command. The sampling plan concentrates on the size fraction of planktonic organisms for which invasions are well documented and is based on four key areas: (1) review of vessel engineering logs to track ballast volume and sources, and management practices; (2) examine the physical and chemical characteristics of ballast water, such as temperature, salinity and dissolved oxygen; (3) quantify planktonic biota community structure/concentration; and (4) perform statistical analyses of the relationship to ship type, year, management practices, and physical/chemical characteristics. Researchers have developed a comprehensive decision tree for choosing ships and ballast tanks for sampling. The concentration of organisms and diversity of the ballast tank communities were related to the physical and chemical characteristics of the ballast water, where and when the ballast was loaded, conduct of management practices, type of vessel, and season and year.

BENEFIT: Data to determine if and how discharges from DoD vessels contain aquatic invasive species, and how these vessels should be managed will be the immediate outcome of this project. This effort will lead to the development of cost-effective, environmentally-compliant treatment and monitoring technologies or management strategies, designed to control the spread of invasive organisms, and meet the unique operating requirements of DoD vessels without jeopardizing operations or ship safety. This project is coordinating research efforts with SERDP project CP-1244.

ACCOMPLISHMENTS: Researchers have sampled 16 vessels, 6 on the east coast and 10 on the west coast. Data analysis for these vessels continues. In addition, researchers evaluated the effect of hull coating characteristics, maintenance practices, vessel type, and home port on the occurrence of fouling. Analysis of maintenance practices, vessel and hull coating type will be conducted for Navy vessels using the hull inspection database maintained by the Naval Sea Systems Command. A remotely-operated vehicle was used to quantify the extent of fouling on ships' hulls, while divers collect qualitative samples to generate estimates of species richness for the fouling community, and determine whether non-indigenous species are present.

TRANSITION: Results from the proposed research will support the activities of the Unified National Discharge Standards (UNDS) program. This program is intended to analyze discharges from DoD vessels, and develop performance standards for pollution control devices that may be employed to treat these discharges. The data obtained will guide the formulation of scientifically-defensible treatment standards under the UNDS program, and the development of effective pollution control devices, by providing information on the abundance and types of organisms found in ballast water and as fouling on hulls.

PROJECT SUMMARY

PROJECT TITLE & ID: Temporal and Modal Characterization of Department of Defense Source Air Toxic Emission Factors; CP-1247

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Gullett, U.S. Environmental Protection Agency, Research Triangle Park, NC

FY 2004 FUNDS: $598K

DESCRIPTION: Air toxic emission factor data are lacking, in part, due to the inability of current methods to address pollutant- and source-specific sampling and analytical challenges. This is particularly true for any kind of emission factors that adequately reflect the use mode and temporal nature of air toxics. This project will develop an integrated methodology for measurement of trace organic and metallic air toxics using three methods: modified conventional measurements, state of the art laser-based technologies, and optical path monitoring to develop and test a sensitive, time-resolved methodology for detection of trace toxics that can be applied to mobile and stationary sources. The combination of measurement methods provides a triangle of overlapping, confirmatory analyses that cover the broad range of organic and metallic air toxics. The project approach will combine three supportive measurement technologies, assessing multiple source type air toxic emission factors under use-mode and temporally relevant conditions. Due to technology overlap in terms of pollutant types, temporal spans, and modal relevance, this project can develop pollutant-to-pollutant correlations. Resonantly Enhanced Multiphoton Ionization (Jet-REMPI) and Laser-Induced Breakdown Spectroscopy (LIBS) use a common seed laser source (Nd:YAG), providing an integrated, common platform for detection of most organic and metallic air toxics.

BENEFIT: Data from these efforts will be used to determine source- and mode-specific emission factors for use in the Air Force's Air Permit Information Management System (APIMS), an emission inventory system currently used by Hill Air Force Base (AFB) and being adopted DoD-wide, as well as to improve EPA's AP42 emission factor system. DoD will benefit from understanding how its base operations contribute to levels of ambient air toxics, both from a standpoint of being able to minimize impacts of potential operating restrictions as well as understanding how to limit occupational exposures (so called "hot spots"). Source identification and emissions characterization, coupled by an understanding of how specific modes of source sampling lead to emissions, will provide DoD with an effective tool for emissions impact minimization.

ACCOMPLISHMENTS: To ionize hexane and butadiene, a single photon ionization capability was developed, implemented and applied. The fieldable, compact, broadband Optical Parametric Oscillator (OPO) laser system was evaluated (Opotek Vibrant). Tests were performed for the following air toxics: benzene, xylenes, toluene, aniline, phenol, ethylbenzene, and chlorobenzene. Results suggest that the compact OPO can be successfully applied to field measurements. For simple and maintenance-free introduction of gas phase samples, a capillary based inlet was designed and incorporated in a newly built ionization chamber. This inlet will improve the fieldability of the system. Metals emissions from a diesel generator source were measured using EPA Method 29. Five separate method 29 sampling trains were used to determine the concentration of antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, and nickel in the generator exhaust. The concentrations ranged from the low ppb levels for all the metals except antimony and arsenic, where the concentrations were in the low parts per million (ppm) range. The emission factors are consistent with those in the published literature, with the exception of antimony and arsenic. Numerous monocyclic and polycyclic aromatic compounds were detected individually in the generator exhaust using jet REMPI. Analysis has been completed, and a peer-reviewed journal article is in the final stages of the EPA clearance cycle. In parallel with jet REMPI, samples were taken using conventional U.S. EPA methods. Results from GCMS analysis and an on-line GC were found to be in fair to good agreement with jet REMPI results.

TRANSITION: Project methods and technologies will be published in peer reviewed literature and promoted through establishment of a Project Advisory Council (PAC). The project will work with the EPA Emission Inventory Group and the Air Force APIMS program for incorporation at DoD facilities. The combined technical expertise, military involvement, and multi-office EPA involvement ensures that the project output will receive broad and accepted use.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Validation of a Predictive Model to Assess the Impact of Coastal Operations on Urban Scale Air Quality; CP-1253

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alan Gertler, Desert Research Institute, Reno, NV

FY 2004 FUNDS: $329K

DESCRIPTION: Many east and west coast U.S. urban areas, classified as non-attainment for ambient air pollutants, are home to major DoD facilities. DoD operations can be significant sources of air pollutants and their precursors. However, there is considerable uncertainty associated with emission inventories of these coastal areas. This project aims to develop and validate a prognostic modeling system capable of assessing the impact of coastal DoD operations on air quality. Included in this objective are the determination of primary and secondary pollutant concentrations, as well as their spatial and temporal variation. The goal is to develop a tool that helps in the design and implementation of effective strategies to reduce the impact of DoD operations on air quality in coastal urban areas. This project uses a method that links state-of-the-art meteorological, transport, and chemical modules by coupling a Lagrangian random particle dispersion model with an Eulerian chemical model. The impact of emissions inventory and meteorological parameter uncertainty on the model predictions are estimated. The model system is validated using real-world data obtained from a series of aircraft measurements performed in the San Diego area.

BENEFIT: The result of this study will enable DoD to (1) predict the impact and influence of coastal DoD facilities on urban and regional air quality; (2) assess the contribution from individual sources to primary pollutant (directly emitted from sources) and secondary pollutant (formed by chemical reactions in the atmosphere) levels; (3) estimate the impact of new technologies, fuels, and activity patterns on air quality; and (4) design effective abatement strategies for primary pollutants and secondary pollutant precursors.

ACCOMPLISHMENTS: The initial emissions inventory for the domain was completed. This was based on the California Air Resources Board (CARB) annual emissions inventory and enhanced using the Southern California Ozone Study (SCOS) and Barrio Logan inventories. Procedures were developed and implemented to obtain real-time access to meteorological forecast fields from the Naval Postgraduate School (NPS). Collaboration was established and meetings held with National Oceanic and Atmospheric Administration (NOAA) to possibly build upon the HYSPLT-Chem model. Model validation work dominated project efforts in 2003. The aircraft sampling plan was finalized and sampling/flight protocols developed. During July 2003, a total of 10 flights were performed in the San Diego area using a Twin Otter platform. Measurements were made for CO, CO_2, O_3, SO_2, NO, NO_2, NOx, NOy, NOz, nitrate, speciated volatile organic compounds (VOCs), speciated aldehydes, bscat, wind speed/direction, temperature, relative humidity, pressure, and altitude. Overall the systems functioned properly. Data validation has been completed and the database for testing the model finalized. All gaseous data have been checked and adjusted based on the in-flight calibrations. Graphs of concentration vs. flight track have been produced for all parameters. For selected species and ratios of species, spatial concentration plots (i.e., two dimensional concentration surfaces) have been interpolated from the concentration vs. flight track data.

TRANSITION: The model will be transferred to San Diego area military installation environmental personnel for application and to other coastal areas. The approach will be communicated and the model possibly transferred to other potential users.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Fate and Transport of a New Energetic Material, CL-20; CP-1254

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Kuperman, U.S. Army Edgewood Chemical Biological Center, Aberdeen Proving Ground, MD

FY 2004 FUNDS: $473K

DESCRIPTION: The primary objectives of this research are to (1) determine transport and fate of CL-20 using a standardized intact soil-core microcosm system, (2) quantify the toxicity of CL-20 to soil invertebrates and plants in soil supporting high chemical bioavailability, and to aquatic biota, and (3) examine the effect of a simulated weathering/aging process on CL-20 toxicity. The research will be conducted in two phases. In phase one the toxicity of CL-20 to soil invertebrates, terrestrial plants, and aquatic species will be quantified. The range of CL-20 concentrations tested will provide a continuum of exposure concentrations from "no effect" to "bioaccumulation levels" to "lethal levels," ensuring investigation of biological and chemical relationships across orders of magnitude in exposure concentration. In phase two transport and fate of CL-20 using standardized intact soil core microcosms will be characterized. Concentration levels will be determined from the results of the definitive toxicity tests conducted in phase one, and will include at least one safety factor of five above the EC50 level. Transport and fate will be assessed in the soil layers, plant and invertebrate materials, and leachates throughout the study period. Aquatic toxicity assays will be conducted with leachates to supplement information on potential toxicity of CL-20 in groundwater following transport through the vadose zone. This project is collaborating with CP-1255 and CP-1256 to develop CL-20 analysis methods.

BENEFIT: The results of these studies will provide potential cost savings to both risk assessment and remediation processes. In the past, chemicals similar in nature to CL-20 were released into the environment without knowing the fate and effects of these compounds. Millions of dollars and thousands of man-hours have been spent on risk assessment and remediation of previously released energetic compounds. By determining the chemical and physical fate of CL-20, as well as toxicological thresholds in aquatic and terrestrial environments, production, training, and disposal operations may be designed to avoid sensitive soils or ecosystems.

ACCOMPLISHMENTS: Range-finding and definitive toxicity tests were conducted with various aquatic species in directly amended aquatic media, and range-finding tests have been conducted in water-based extracts from CL-20 amended soil. Definitive tests for assessing CL-20 effects on the soil invertebrates were conducted in freshly amended and weathered/aged CL-20 amended soils. This new design of the soil biota microcosm system has facilitated the assessment of CL-20 effects on litter decomposition, a critical ecosystem-level functional assessment endpoint. Intact soil cores were collected and are undergoing evaluation. The results of the second year's investigations provided critical information for planning investigations of CL-20 toxicity in the third year of the project.

TRANSITION: This research project was designed to generate toxicity data for CL-20 that can be used directly for the development of screening levels according to the draft "Ecological Soil Screening Level (Eco-SSL) Guidance" (U.S. EPA) and protective benchmarks for aquatic species. The data transition to U.S. EPA will be facilitated because project personnel are associated with the Eco-SSL National Task Group for developing Soil Invertebrate and Plant Eco-SSLs.

PROJECT SUMMARY

PROJECT TITLE & ID: Factors Effecting the Fate and Transport of CL-20 in the Vadose Zone and Groundwater; CP-1255

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Szecsody, Pacific Northwest National Laboratory, Richland, WA

FY 2004 FUNDS: $440K

DESCRIPTION: Hexanitrohexaazaisowurtzitane (CL-20 or HNIW) is a promising replacement for existing propellants and explosives, since it releases more energy on ignition and is more stable to accidental detonation than energetic materials that are currently used. Wastes associated with the DoD energetic materials constitute a major fraction of the DoD hazardous waste inventory; therefore, it is critical that DoD consider the environmental fate and reactivity of CL-20 in sediments and in groundwater. The objective of this project is to characterize the fate and transport of CL-20 in subsurface sediments, focusing on the identification and quantification of geochemical and microbial reactions of CL-20 in sediments, the effects of weathering, and the influence of transport on these reactions in the subsurface environment. Geochemical and microbial reactions are investigated using simple (e.g., uncoupled batch experiments) to more complex systems that represent field-scale transport (e.g., one-dimensional [1D] unsaturated/saturated transport, coupled reactions in natural sediments). Geochemical reactivity in batch systems is used to quantify sorption mass, rate, and reversibility as well as abiotic degradation pathway and rates. A mechanism-based reactive transport model is used to predict CL-20 fate for a range of theoretical scenarios where CL-20 is released into the subsurface environment. This project is collaborating with CP-1254 and CP-1256 to develop CL-20 analysis methods.

BENEFIT: By characterizing the fate and transport of CL-20 in the subsurface, the DoD has the ability to determine the appropriateness of CL-20 as a replacement for currently used propellants and explosives that are known to contribute to DoD hazardous waste inventory.

ACCOMPLISHMENTS: Results of this study show that in most cases CL-20 exhibits low sorption and low degradation rates with subsurface sediments, so CL-20 would persist in the subsurface environment and be at risk for deep migration. Some sediments exhibited more rapid degradation rates. The abiotic degradation rates are significant for specific 2:1 clays (biotite, hectorite, and montmorillonite) and adsorbed iron (FeII), so identification of these minerals in sediments would enable prediction of CL-20 abiotic degradation rates. This study has shown that while CL-20 is persistent in some sediment environments (i.e., and exhibits high risk for deep migration), different remediation techniques can be used to degrade CL-20. A reducing environment (abiotically or biotically created) will rapidly degrade CL-20, as will elevated temperature (>40°C) or alkaline conditions (pH >9.0).

TRANSITION: Information from the results of this proposed work will be disseminated to the scientific community through peer-review publications. There will be an interlaboratory comparison of data to assess risk to the environment relative to other energetic compounds. Results of this proposed work, along with other CL-20 projects, will additionally be disseminated to DoD program managers through briefs and workshops for the purpose of providing information of CL-20 impact in the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Fate and Transport of a New Energetic Material, CL-20; CP-1256

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari, Biotechnology Research Institute, NRC, Montreal, Quebec, Canada

FY 2004 FUNDS: $80K

DESCRIPTION: High density polynitropolyaza-caged compounds contain high energy that attracts the military to use them as high energetic explosives and propellants. A typical energetic chemical of this family commonly known as CL-20 is being considered a potential replacement for existing propellant and explosive materials; however, it has been recognized that the potential environmental fate and impacts of this compound must be understood prior to its adoption as a common energetic material. Previous practices involving manufacturing, waste discharge, testing and training, demilitarization, and open burning/open detonation (OB/OD) of explosives such as RDX and HMX, have resulted in severe soil and groundwater contamination. Future military-wide practices with CL-20 may also result in environmental contamination of soil and groundwater. The project is investigating the transport and the biotic and abiotic degradation of CL-20, and studying the lethal and sub-lethal environmental effects of CL-20 on terrestrial higher plants, soil invertebrates, soil microorganisms, and avian and aquatic species. This project is collaborating with SERDP projects CP-1254 and CP-1255 to develop CL-20 analysis methods.

BENEFIT: Scientifically sound and convincing environmental data (transport, transformation and ecotoxicological effects) generated on CL-20 from this project will provide military personnel and other site managers with a knowledge base to help understand and predict the fate and environmental impact of CL-20.

ACCOMPLISHMENTS: Two methods based on HPLC and capillary electrophoresis, respectively, were developed for the analysis of CL-20 and its degradation products. Based on this work, a standard operating procedure was prepared for the analysis of CL-20 in soil and water and validated through an interlaboratory study with the two other SERDP CL-20 projects (CP-1254 and CP-1255). The stability and solubility of CL-20 in water were determined at different temperatures (solubility: 5 to 60°C, stability: 10, 20, and 3°C). Key findings have shown that CL-20 can be degraded abiotically (hydrolysis and photolysis). In both cases nitrite, nitrous oxide and formic acid were detectable. Three highly polar intermediates resulting from hydrolysis of CL-20 were also detected and will be isolated for further identification. Significant progress in understanding the mechanism of CL-20 photodecomposition was made with the detection and tentative identification of several transient intermediates. Findings have shown that CL-20 can be degraded biotically under both aerobic and anaerobic conditions. CL-20 toxicity range-finding tests were conducted using selected aquatic species (freshwater green algae) and terrestrial organisms (microbes, invertebrates, plants and Japanese quail). Data indicated that CL-20 was not toxic to the aquatic species tested (up to the aqueous solubility limit of CL-20). Also, CL-20 did not show adverse effects to higher terrestrial plants (perennial ryegrass and alfalfa) and to Japanese quail, up to 10,000 mg/kg soil and 5,000 mg/kg body weight, respectively. In contrast, CL-20 showed lethal and sub-lethal effects on selected soil invertebrates (earthworms and enchytraeids). Sorption isotherms of CL-20 were conducted to determine the bioavailability of CL-20 in several soils differing in pH, mineral phases and organic content. CL-20 was highly retained by the organic fraction of soils, and the sorption was governed more by the type of organic matter than the amount. Moreover, sorption slightly retards but does not prevent CL-20 hydrolysis in soils with pH >7.5.

TRANSITION: The knowledge of (bio)degradability and ecotoxicity of CL-20 generated from the laboratory work will allow the prediction of its environmental fate and effects in the field. This information can be used by the DoD to help make implementation or deployment decisions on CL-20. If CL-20 is adopted, this information can also be used by site managers and engineers to help design any possible

remediation plans at contaminated sites. Additionally, successful laboratory bench-scale microcosms for the degradation of CL-20 can provide the fundamental data for pilot-scale demonstration work and for optimizing engineering parameters for field applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Acoustic Models for Military Aircraft Noise Propagation and Impact Assessment; CP-1304

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kenneth Plotkin, Wyle Laboratories, Arlington, VA

FY 2004 FUNDS: $856K

DESCRIPTION: Current environmental noise models used by the DoD to assess the impact of military aircraft operations are not appropriate for the new generation of fighter aircraft with high performance engines and vectored thrust capabilities which could lead to the potential to lead to restrictions in flight operations at airbases and within training airspaces. New models are needed to provide legally defensible noise assessments of current and future aircraft operations in protecting bases and airspace for training purposes and in minimizing restrictions based on noise. The objective of this project is to provide environmental specialists with tools, based on the latest technology, for assessing and mitigating the noise impact around bases and on ranges of the new generation of fighter aircraft operating under all possible weather and terrain conditions. The research effort will consist of two main elements. The first will be a series of numerical, laboratory, and field studies to develop practical models for nonlinear generation and propagation of noise from high-thrust, vectored jet engines. The second element will be development of computer simulation procedures for the visualization of the resultant dynamic noise fields.

BENEFIT: The information developed under this study will represent a significant advance in the understanding of non-linear propagation from high-level noise sources and in the measurement of aircraft source noise levels. This will allow DoD to more accurately estimate the noise environment from aircraft operations and provide a scientific foundation for installation commanders in responding to criticisms from knowledgeable citizens on the appropriateness of these estimates. These tools will assist DoD in being responsive to regulatory requirements while protecting operational readiness from unreasonable restrictions based on today's limited knowledge of nonlinear noise effects.

ACCOMPLISHMENTS: An analysis of the F/A-18E noise data collected at Naval Air Warfare Center Aircraft Division (NAWCAD) Lakehurst, NJ site was performed. These data were provided for comparison to theoretical predictions. High frequency effects, which are important for the documentation of non-linear effects in the time-domain, were obscured by a ringing response in the recorded signals. These problems have been identified and solutions have been found which will involve the use of different microphone systems. Existing rocket noise data sets were re-analyzed and analyses/metrics reflecting the non-linear behavior of the noise were developed. The results of these analyses have been summarized in a paper submitted to the Journal of the American Statistical Association. Laboratory experiments have focused on improving the accuracy of the time records of pressure fluctuations in the far acoustic field. A method of obtaining corrected time series data was developed to remove the microphone response inaccuracy and the atmospheric attenuation effect.

TRANSITION: The product will allow planners to incorporate a completely new set of operational scenarios and features, which will assist in public presentation and understanding of potential noise impacts and their mitigation. One of the main deliverables of this project will be a new aircraft noise model for the assessment of community and environmental impacts. This will provide planners and environmental analysts with the best tools in a short amount of time.

PROJECT SUMMARY

PROJECT TITLE & ID: Impacts of Fire Ecology Range Management (FERM) on the Fate and Transport of Energetic Materials on Testing and Training Ranges; CP-1305

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Hinchee, Battelle Memorial Institute, Columbus, OH

FY 2004 FUNDS: $284K

DESCRIPTION: There exists a growing concern that the accumulation of unexploded or unconsumed energetic compound residues in soils on military testing and training ranges represents a threat to human health and the environment. These residues, which can take the form of discrete "chunks" or very fine particles, may dissolve and leach into groundwater or be carried offsite in runoff. This illustrates the need for range management practices that effectively reduce inventories of energetic residuals, thereby avoiding costly environmental cleanup projects and disruptions in DoD training activities.

The objective of this project is to determine the degree to which prescribed burning reduces surface and near-surface energetic residuals in range soils and their fate and transport. Variables such as burn intensity, soil depth, and vegetation density will be measured to quantify the conditions necessary to optimize reduction of energetic residuals. The observed energetic contaminant destruction will be assessed in terms of mass loadings of energetic compounds in surface water runoff from controlled test plots. Results from this study will be used to develop burn scenarios that help reduce the inventory of energetic contamination on ranges without compromising the benefits of burning to achieve specific land management objectives. Specific attention will be devoted to the relationship between energetic residuals and native plant species, and how that relationship can be exploited to enhance the destruction of the energetic contaminants.

BENEFITS: Documenting the impact prescribed burning has on energetic residuals can serve as a basis for developing prescribed burning strategies that maximize the destruction of energetic residuals, thereby minimizing the likelihood of widespread environmental contamination. The long-term potential benefit to the DoD will be the deployment of a range management tool that may prevent the need for costly environmental cleanup projects and help avoid interruptions in training activities caused by environmental and/or regulatory concerns.

ACCOMPLISHMENTS: Site selection and range characterization have been fully completed, and the laboratory thermal decomposition study is ongoing. The initial trinitrotoluene (TNT) experiments have been completed and the initial hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) experiments are nearly complete. Migration and Gas-phase studies, which were an addition to the original laboratory scope, are ongoing for TNT and RDX and should be complete by Spring 2004. Development of an experimental burn plan is ongoing and has required an additional visit to Eglin Air Force Base (AFB) to discuss the technical approach with base staff. This visit included a site walk with controlled burn specialists and Explosive Ordinance Disposal (EOD) technicians from Eglin to finalize the burn approach at the site and to work out some of the logistical details which will involve subsurface digging for sampling and placement of instrumentation for the burn event.

TRANSITION: In addition to project team members working cooperatively with members of the DoD user community, findings will be presented at various professional symposiums and submitted for publication to peer-reviewed journals. Finally, this work may lead to the development of a guidance document that describes the use of prescribed fire to mitigate hazardous caused by energetic residuals.

PROJECT SUMMARY

PROJECT TITLE & ID: On-Range Treatment of Ordnance Debris and Bulk Energetics Resulting from Low-Order Detonations; CP-1330

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Philip Thorne, Applied Research Associates, South Royalton, VT

FY 2003 COMPLETED PROJECT

DESCRIPTION: Low-Order Detonation (LOD) debris is poorly characterized and a potential source of contamination to groundwater beneath live-fire testing and training ranges. This project aimed to develop a low-cost, fieldable process for the rapid decontamination of energetic materials (EM) from bulk compositions and LOD debris. The on-range process consisted of rapid decomposition, dissolution and hydrolysis to separate and destroy EM from metallic debris. Data was acquired to evaluate chemical processes for treating the decontamination solutions on-site without acquiring hazardous wastes. Ordnance debris with visible EM residues and "chunks" of EM compositions was collected manually or robotically and segregated. The contaminated items were placed in tanks containing polyglyme (polyethylene glycol dimethyl ether)/sodium hydroxide solution, which was re-circulated until EM residues decomposed and dissociated from the scrap. The scrap was then removed and sent off-range for recycling. Dissolved EM was hydrolyzed and the polyglyme/hydrolysate chemically destroyed using combustion or hydrothermal oxidation. Simple field colorimetric analysis was used to determine when enough of the EM had been hydrolyzed so that thermal treatment could be safely performed.

BENEFITS: The flexibility (applicability on different scales), safety, simplicity and low costs associated with this decontamination technology facilitate its use by site personnel. The capability for handling LOD debris and "chunk" energetics reduce the amount of hard-to-handle unexploded ordnance (UXO) that must be processed by site personnel, resulting in improved safety and lower disposal costs. Some costs may be offset by using the decontamination solution as a co-fuel. Implementation of the new process is also likely to reduce the need for wide-area decontamination, reducing cleanup costs by dealing with the most contaminated materials.

ACCOMPLISHMENTS: Initial experiments showed that the dissolution of trinitrotoluene (TNT) and Composition B was rapid with polyglyme. Several pounds of EM were dissolved and hydrolyzed per a gallon of polyglyme; however, it is currently expensive ($30/gal). If it is consumed in the thermal treatment that follows hydrolysis, the cost is approximately $10/pound explosives neutralized. In a second field trip to Nellis Air Force Base (AFB), experiments were conducted to investigate the use of heat to speed the dissolution and hydrolysis of EM from LOD. Polyethylene glycol was also investigated as a less expensive high-boiling solvent. Aliquots of sodium hydroxide were added to the hot glycol solution to initiate hydrolysis, while the solution was stirred continuously and the temperature monitored for the duration of the experiment. Lab results showed that this decontamination technology essentially destroyed all EM from the LOD samples. After examining dissolution and hydrolysis solutions from the initial field test, chemical engineers at Applied Research Associates (ARA) proposed a thermal treatment termed Catalytic Hydro-Thermal Conversion (CHTC) operated at about 700°C and low pressure, slightly above one atmosphere. Assembly of a lab-scale CHTC prototype is underway at ARA-Florida.

TRANSITION: The technology will be introduced at several ranges as the first transition step. It is expected that familiarity with the process and its performance will encourage those ranges to adopt the technology for full-scale remedial clean-ups and for the more extensive routine clearances that will be required once the LOD debris problem is fully recognized.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Off-Road Diesel Emissions of Criteria Pollutants; CP-1336

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Watson, Desert Research Institute, Reno, NV and Dr. Wayne Miller, University of California, Riverside, CA

FY 2004 FUNDS: $922K

DESCRIPTION: As a result of their reliability and fuel economy, diesel engines have become the preferred power source for many activities at DoD facilities. Emissions from these activities are currently not well understood, making it difficult for environmental staff on military installations to provide emissions information needed for state and regional planning. Quantification of particulate matter (PM), NOx, sulfur dioxide (SO_2), volatile organic compounds (VOC), and other chemicals from diesels in military use is needed to develop effective policies that will achieve current and future air quality standards. The primary objective of this project is to develop source-, use-, and fuel-specific emission estimates for representative DoD mobile and stationary diesel equipment, most of which is not extensively used on paved public roadways. These estimates must meet the minimum requirements of the Consolidated Emissions Reporting (CER) rule for emission rates of carbon monoxide (CO), NOx, VOC, PM_{10}, $PM_{2.5}$, SO_2, and ammonia (NH_3). A second objective is to develop, test, and apply new methods for quantifying non-road emissions that more efficiently and realistically represent actual operations than engine dynamometer certification tests. The final objective is to integrate these results into U.S. EPA non-road emissions and source profile software and to create an emissions modeling system that permits quick and efficient estimates to be made for military installations.

BENEFITS: The project will provide the DoD with new emission measurement technologies and improved emission inventories for use in assessing progress toward improving air quality and assessing progress for national air quality standards and visibility goals.

ACCOMPLISHMENTS: Army data have been extracted from the Operating and Support Management Information System (OSMIS) relational database and placed into a data table, which includes equipment identifiers, the number of units at each location, the type of fuel used by each type of equipment, the miles traveled and cost of fuel consumed. Marine Corps data have been assembled into a single spreadsheet and classified by operating sub-unit. The in-plume monitoring system was assembled and tested at Incline Village (Lake Tahoe, NV) under the auspices of the California Air Resources Board. A subsequent test was completed in Las Vegas, NV under the auspices of the Clark County Air Quality Management Division. In addition to acquiring valid data, these tests verified the systems integration of the Fourier Transform Infrared Spectrometer (FTIR) and Electrical Low Pressure Impactor (ELPI). Two in-plume configurations were used: (1) a speed-bump with an opening to capture near-road exhaust plumes of passing vehicles; and (2) an extended tubular inlet placed manually in the visible exhaust of elevated plumes (e.g., diesel buses). Assembly of the second generation cross-plume lidar sensor is underway for use with the in-plume system on tests of on-road vehicles in Las Vegas, NV and school buses in Boise, ID.

TRANSITION: The products of this research are: modern non-road exhaust test methods; documented databases of emissions measurements for many different fuel/engine/use combinations; integration into national NONROAD and SPECIATE software; and an easy to use emissions model tailored to military applications. Data sets and models will be available via the internet, and one training course will be organized and conducted. Measurement technology will be commercialized, when possible.

PROJECT SUMMARY

PROJECT TITLE & ID: Tailpipe Emission Estimation for Department of Defense Off-Road Sources; CP-1338

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Kemme, U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory, Champaign, IL

FY 2003 COMPLETED PROJECT

DESCRIPTION: Emissions from tactical equipment engines contribute to local and regional air pollution during training activities. The emissions from these DoD sources are not well understood and will likely differ significantly from the emissions of similar civilian sources. Differences are likely because the fuels, vehicle usage patterns, and engine technologies are not the same. Although many of these sources are exempt from regulations that limit these emissions from comparable civilian sources, DoD installations still must be able to answer regulatory questions about the impacts these sources have on air pollution problems. The objective of this research was to develop a database of DoD off-road sources and their training activity. Regulatory acceptance of this database will be facilitated by teaming with the U.S. EPA personnel who will evaluate its adequacy. The database will be used to assess and prioritize DoD equipment and provide information required to estimate emissions, which will directly support the SERDP funded project: Characterization of Off-Road Emissions of Criteria Pollutants (CP-1336).

BENEFITS: The primary benefits of this research are its contribution to the development of a tool to accurately estimate engine emissions for DoD off-road sources. This capability is useful to DoD environmental staff, installation managers, and designers of military training ranges, who must estimate the environmental impacts of off-road diesel emissions and develop recommendations for reducing these emissions. The database of DoD off-road sources and activity levels is also a useful tool for researchers investigating other environmental impacts related to off-road diesel engine use.

ACCOMPLISHMENTS: The Navy and Marines Visibility and Management of Operating and Support Costs (VAMOSC) database systems were identified as sources of activity data for the Navy and Marines. The Air Force Total Ownership Cost (AFTOC) database system was identified as a source of Air Force activity data. Data tables of fuel properties, diesel-powered equipment, and diesel engines employed by Army and Marines were created. Army diesel powered equipment inventory, activity, and fuel usage information was also created and matched with the Army equipment and diesel engine data tables.

TRANSITION: All the products of this research will be approved and provided to the U.S. EPA for dissemination. Military personnel will be able to obtain the emission estimation technology through the U.S. EPA or through commonly visited Internet sites (i.e., Defense Environmental Network and Information eXchange-DENIX).

PROJECT SUMMARY

PROJECT TITLE & ID: Assessing the Impact of Maneuver Training on the NPS Pollution and Water Quality; CP-1339

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Steichen, Kansas State University, Manhattan, KS

FY 2004 FUNDS: $354K

DESCRIPTION: Military training maneuvers have the potential to significantly alter land surfaces in a manner that promotes Non-Point Source (NPS) pollution, preventing military installations from meeting water quality standards and the decline of training lands. In order to avoid training operation restrictions, proactive management plans must be developed to give commanders the information they need to assess the environmental cost of training and management practices that reduce the environmental impact.

Investigators will assess the impact of two major sources of NPS pollution on surface water quality at Ft. Riley, Kansas: (1) erosion from upland training areas and (2) channel erosion at stream crossing sites. These objectives will be met through a comprehensive analysis of military activities, climatic factors, and environmental response. Researchers will use a watershed water quality model in conjunction with remotely sensed information and a geographic information system (GIS) to assess the impact of training on water quality, in particular on the amount of soil erosion. Particular attention will be paid to linking weather, vegetation stage, and training activities to water quality. A matrix of training intensity and weather will be created to give commanders a tool for assessing the environmental cost of training maneuvers. Researchers will instrument three buffer sites with runoff samplers to determine the effect of vegetated buffers for controlling NPS pollution. A complete survey characterizing the buffer, including vegetation and soil characteristics, will be conducted at each field site. The Riparian Ecosystem Management Model (REMM) will be adapted to each site and provide a tool for determining the optimal buffer width to control soil erosion caused by military maneuvers. New real-time data collection systems will be developed and installed at Low Water Stream Crossings (LWSCs) to assess the impact of vehicle crossings on stream water quality and erosion dynamics.

BENEFITS: Land managers will benefit from the design guidance that will assist them in maintaining and enhancing riparian filter areas for water protection. An environmental decision support tool will allow Commanders to guide their decisions on the use of training lands and the potential for environmental damage.

ACCOMPLISHMENTS: Troop training data has been compiled for the last five years, and geographic information system (GIS) layers maintained by Ft. Riley were obtained (e.g., installation boundary, training areas) and supplemented with additional and derived layers (seamless digital elevation, slope, and aspect). Additional GIS data is being compiled to support soil moisture estimation activities. A complete Ft. Riley climatology has been developed from the National Weather Service and cooperative stations across Kansas. Included in the climatology was a local estimate of Rainfall Erosivity (R-factor), one of the components in the Revised Universal Soil Loss Equation (RUSLE). Daily and 16-day composite MODIS satellite data, collected for the Ft. Riley area, will be used in both soil moisture estimation and vegetation impacts tasks. The Ft. Riley GIS was used for preliminary site selection. Six potential sites were identified based on slope, aspect, vegetation, training intensity, and proximity to a LWSC. Fabrication of the Runoff Surface Samplers (ROSS) is complete and calibration is underway. Laboratory experiments using optical measurements of turbidity were successful. Work on facilitating wireless transmission for sensor signals is underway.

TRANSITION: A better understanding of the characteristics of sediment-laden runoff and the effectiveness of riparian filter strips will be useful for many installations. Results from this study will culminate in a model for assessing the impact of military training and weather on NPS pollution and TMDL compliance. Ft. Riley

is representative of several maneuver posts located in the central U.S. Project results will be transferred to military installations by workshops and field trips at the U.S. Army Integrated Training and Management (ITAM) Workshop sponsored at Ft. Riley near the end of the project.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of an Adaptive Framework for Management of Military Operations in Arid/Semi-Arid Regions to Minimize Watershed and Instream Impacts from Non-Point Pollution; CP-1340

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Wigmosta, Pacific National Northwest Laboratories, Richland, WA

FY 2004 FUNDS: $325K

DESCRIPTION: To ensure adaptability in managing training operations while minimizing impacts on watersheds, the DoD needs to identify activities that contribute to non-point source (NPS) pollution, and strategically locate and schedule training operations to minimize impacts. Decision tools are needed that provide information to articulate tradeoffs between alternative management actions and resultant impacts and/or benefits to training range or adjacent downstream water bodies. A set of decision tools, process models, and GIS databases will be assembled, linked and integrated as an adaptive management framework that will allow DoD to minimize constraints on training exercises while ensuring protection of watersheds and compliance with Total Maximum Daily Load (TMDL) targets. The decision tools will assist in optimizing design and implementation of operations, management plans, and policies while accounting for uncertainties. They will be supported by state-of-the-art watershed/erosion models and GIS models linked to tailored remotely sensed and conventional databases. NPS pollution resulting from military training activities will be identified using advanced pattern recognition techniques to characterize spatial variability and changes in soil and vegetation. The level of impact will be quantified in the form of hydrologic model input parameters. The framework will be accessible via the Internet. The practical utility of the adaptive management framework for managing training operation environmental impacts in arid/ semiarid regions will be demonstrated at the Yakima Training Center, WA.

BENEFITS: DoD will benefit from an adaptive management tool for more effective, streamlined, and integrated operational and environmental planning at military bases in arid and semiarid regions. Improved management of training lands will help maintain sustainable training facilities, protect water quality and the natural resource base while avoiding violations of TMDL and other regulations.

ACCOMPLISHMENTS: The conceptual model of management alternatives at the Yakima Training Center (YTC) was completed. The YTC data inventory was also completed and transferred to the YTC. The first year of remote sensing fieldwork is complete. Development of model parameter estimation algorithms as well as a prototype application to roads and firebreaks is ongoing. The assessment of available hydrological data is complete along with the first year of hydrological/erosion field data collection. A Hillslope Erosion Model was developed for a preliminary estimate of erosion from measured hillslope transects. Testing of the hydrological model to simulate rain-on-snow-on-frozen soil conditions is underway. A project website was developed (http://yakimaserdp.pnl.gov/), and a draft report *"Field Data, Modeling, and Analysis for Assessment of Soil Erosion and Sediment Yield from Hillslopes at the Yakima Training Center"* is under final review.

TRANSITION: The adaptive framework to be developed under this project will be demonstrated/ transferred and made fully operational for use at the YTC on their computer systems. YTC staff will be fully instructed in the use of the framework. Materials produced for this technology transfer process will be designed to facilitate broad transfer to other military facilities as well.

PROJECT SUMMARY

PROJECT TITLE & ID: Airborne Weapons Noise Prediction Model; CP-1397

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Micah Downing, Wyle Laboratories, Arlington, VA

FY 2004 FUNDS: $345K

DESCRIPTION: A number of aircraft and ground-based weapon system noise models have been developed over the past 30 years to estimate noise levels from military operations. The results of these models are used to assess the potential for community and environmental impacts from current and proposed operations. Current DoD noise models all use common aircraft and weapon system source noise databases maintained by the Air Force Research Laboratory (AFRL), U.S. Army Construction Engineering Research Laboratory (CERL), and Navy Facilities Engineering Command. These models and the source noise database do not provide the capability to assess noise impacts due to air-borne weapon operations. A new computer model is needed that can model the combination of aircraft noise and elevated weapon noise that occur in air-gunnery operations. The complexity and computational labor involved in assessing noise impact from air-gunnery operations dictates the need for an efficient and flexible software tool.

The objectives of this project are to (1) characterize the noise generated by different types of airborne weapon systems, (2) evaluate and refine current weapon noise propagation algorithms for airborne platforms, and (3) incorporate these refined algorithms and additional input requirements into the new Noise Model Simulation (NMSim) noise simulation model being developed under SERDP project Advanced Acoustic Models for Military Aircraft Noise Propagation and Impact Assessment (CP-1304). This integration will provide for modeling completely new sets of operational scenarios not available in current models, which will assist in public presentation and understanding of potential noise impacts and their mitigation.

BENEFITS: The information developed under this study will represent a significant advance in the understanding of the contribution of air-gunnery operations to the overall noise generated by range operations. This will allow DoD to more accurately estimate the noise environment from aircraft range operations, and provide a scientific foundation for range commanders in responding to criticisms from knowledgeable citizens on the appropriateness of these estimates. These tools will assist DoD in being responsive to the requirements of the National Environmental Policy Act (NEPA) while protecting operational readiness from unreasonable restrictions based on today's limited knowledge of air-gunnery noise effects.

ACCOMPLISHMENTS: This is an FY04 New Start.

TRANSITION: Throughout the project, the combined Wyle-Army team will coordinate closely with the military Services and DoD agencies. As the new models take shape, they will be alpha and beta tested by representatives of these agencies to ensure an efficient transition of the models into the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: Prediction Model for Impulsive Noise Impacts on Structures; CP-1398

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kenneth Plotkin, Wyle Laboratories, Arlington, VA

FY 2004 FUNDS: $226K

DESCRIPTION: The current assessment guidelines used by the U.S. Army to predict the potential for blast damage are overly conservative for long-range propagation. In contrast, existing DoD guidelines for storage of explosives are not accurate for close-range sites and substantially underestimated the risk of window damage. These shortcomings have the potential for limiting training operations that generate impulsive noise, or requiring that such operations be relocated to other training facilities. Existing models for predicting damage and rattle from noise impulses need to be improved with the infusion of new knowledge on blast waveforms and the probability of damage, and these models exercised to develop more precise guidelines that will protect facilities for training purposes, and minimize restrictions on their use.

Project efforts will consist of three main elements. First, blast wave signatures from military operations will be quantified, and existing models for airborne propagation extended. The contribution from ground borne propagation will be measured and modeled as appropriate. Second, the transfer functions between the propagated blast waves and a range of building structures will be modeled, and a formulation developed for the probability of damage. Both of these elements will be based on existing models. A field measurement program will be conducted at four locations. These measurements will address airborne and groundborne propagation, structural response, and modal analysis of selected structures. The measurements will be conducted in sufficient detail that the adequacy of current single-figure criteria metrics can be assessed and improved if necessary. Existing data on the strength of building materials will be extensively analyzed. Finally, guidelines will be prepared to provide information on the assessment of damage from blast waves.

BENEFITS: The information developed under this study will represent a significant advance in the understanding of the effects of blast waves on structures, and in particular the influence of ground propagation on the vibration levels experienced at short and long distances. This will provide military trainers, DoD facility and operations planners, and environmental specialists with tools, based on the latest technology, for assessing the potential for damage and rattling of building components when exposed to impulsive noise signatures generated by military operations. As a result, the product will allow planners to predict damage potential with greater precision, and assist in public presentation and understanding of potential impacts and in the resolution of damage claims. These tools will assist DoD in being responsive to local communities and the requirements of the National Environmental Policy Act (NEPA) while protecting operational readiness from unreasonable restrictions based on the current guidelines.

ACCOMPLISHMENTS: This is an FY04 New Start.

TRANSITION: Throughout the project, the Wyle team will coordinate closely with the military Services and DoD agencies. As the new procedures and criteria take shape, they will be reviewed by representatives of these agencies. This process will ensure a seamless and efficient transition of products into the user community.

APPENDIX C
Conservation Project Summaries

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PROJECT SUMMARY

PROJECT TITLE & ID: Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands; CS-1103

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Antonio Palazzo, U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

FY 2003 COMPLETED PROJECT

DESCRIPTION: Wear-resistant plants are needed to mitigate environmental impacts and improve the use of DoD training lands. Knowledge of the relationships between military training and plant injury, regrowth, and wear resistance is limited. Plant and soil data were combined allowing land users to make knowledgeable choices concerning plant selection and site-rehabilitation procedures to reduce soil erosion. This project used several collections of resilient and other plants to breed new, more resilient cultivars. A second objective was to conduct field and greenhouse studies to quantify the degree of compaction that occurs during training and relate soil condition to root injury in plants with known resilience. A third objective was to evaluate the effectiveness of selected seed mixtures in establishing native plants and resisting invasion of noxious weeds.

BENEFIT: This project provided DoD with guidance for mitigation methods in restoring training lands and provided more resilient plant species that will help to increase training opportunities on existing training areas. This guidance will assist land managers and trainers in making choices on training schedules and in estimating cost and time requirements for maintaining military readiness.

ACCOMPLISHMENTS: Over the past 6 years, the research team successfully improved traits related to resiliency and establishment in introduced and native species of rangeland grass plants. Two new grass cultivars and two new grass germplasms were registered and released via publications in *Crop Science*. The latest release, the native P-7 bluebunch wheatgrass, has been widely accepted by federal land managers because of its increased genetic diversity. Significant advances were made in relating molecular markers to plant characteristics and in using DNA fingerprinting techniques to determine genetic diversity. Markers were used to identify species and determine plants that can grow better at low temperatures. Tools to assess the genetic differences and similarities in commercial and natural seed sources were developed so land managers will be able to confidently select the most cost-effective seed sources that will insure genetic compatibility with existing populations. Tank tracking studies, performed to evaluate the degree of compaction, showed that introduced species are more tolerant and recover more rapidly under repeated tracking than native plants. Two of the native plants, western wheatgrass and Snake River wheatgrass showed promise as stabilization species since they are able to spread into damaged areas. Studies designed to select seed mixtures that allow for earlier land use for training and still end up in the out years with a native plant stand, showed that, as native plants are developed with improved training resilience, they can be used successfully in combination with introduced species to obtain native plant swards. The seed mixtures and equipment used are readily available and the seeding is accomplished in one application, thus saving money.

TRANSITION: This project will be transitioning to ESTCP in FY 2004. The objective of the ESTCP project, “Implementation and Commercialization of New Germplasms for Use on Military Ranges”, is to bring the new germplasms and improved seeding methods to widespread use on DoD and other federal lands by demonstrating and further validating the new plant materials and seeding methodologies, investigating release of cultivars, initiating seed contracts, and developing a planting guide for military facilities in the intermountain west.

PROJECT SUMMARY

PROJECT TITLE & ID: SERDP Ecosystem Management Program (SEMP); CS-1114

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. William Goran, U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory, Champaign, IL

FY 2004 FUNDS: $2483.5K

DESCRIPTION: The SERDP Ecosystem Management Program (SEMP) was established as an outgrowth of the 1997 SERDP Management Scale Ecological Research Workshop during which it was determined that the DoD should establish a long term ecological monitoring program at a military base with possible expansion to some other bases in the future. The overall program objective of SEMP is three fold. First, SEMP directs and selects DoD relevant, ecosystem management research initiatives. Secondly, it manages a long term ecological monitoring system to support these research efforts while also fulfilling some of the host installations monitoring requirements. Finally, SEMP facilitates the integration of results and findings of research into DoD ecosystem management practices. The SEMP is managed by a separate Program Manager with the assistance of a Technical Advisory Committee (TAC).

Under the Ecosystem Characterization and Monitoring Initiative (ECMI), a team works with the host installation to gather, assess and document historic and current ecological data sources and monitoring efforts. In addition, this team is responsible for long term ecological monitoring. Data from the characterization effort, the monitoring efforts and the research teams all flows into the common data repository, shared by all research teams and the installation managers.

Selected research teams work in a collaborative context sharing field sites and approaches, entering data into a common repository, reviewing each other's findings, and contributing to common technology transfer mechanisms. Three research groups were initiated in FY99 to examine ecological indicators. The objectives are to identify indicators of ecological change at multiple spatial and temporal scales, and to establish relationships between ecological indicators and land use. In FY00, two research teams initiated the identification of ecological disturbance from military land use with the objective being to develop the knowledge to implement ecosystem management approaches for military lands.

BENEFIT: DoD's Conservation user community is directed to implement an ecosystem approach to land management issues. However, there is a critical need for scientific information to support this approach, especially as it relates to integrating ecosystem management with mission concerns. The success of user plans will depend on the capabilities and increased knowledge generated by research investment. SEMP will facilitate a number of studies that can be sufficiently planned and funded to allow a full array of remote sensing, ground truth experiments, modeling, cause-effect studies, etc. to be integrated to address complex problems. This contributes to data sharing, leveraging, and joint publications, supported by major experimental findings. Focused development of an ecosystem research plan, appropriate instrumentation and monitoring to support this research, and identification and selection of the most effective, technically sound research efforts to answer user needs will all contribute to the science and understanding necessary for an ecosystem approach to land management.

ACCOMPLISHMENTS: The SEMP TAC met throughout the year to provide recommendations to the program manager on the technical approach and progress of each of the SEMP research projects. The SEMP management team developed an initial technology transfer plan that represents the concept and planning document ensuring that the SEMP work reaches the critical and maximum audience. At the Ecological Society of America annual meeting, held in Savannah, Georgia, over a dozen papers were presented relating to SEMP.

Under the research project Determination of Indicators of Ecological Change, Dr. Ramesh Reddy of the University of Florida, continued to monitor watershed hydrology and preliminary modeling results suggest that an understanding of hydrologic pathways is necessary to link excess nitrogen to stream water chemistry. Ground cover vegetation was assessed within two major soil groups (loamy vs. sandy soils) after logging activities at 32 sites. A second sampling of riparian soils was conducted in support of the Riparian Ecosystem Management Model to account for seasonal trends in carbon and nitrogen inputs to the watershed. Biogeochemical analyses were completed on samples collected in the fall of 2002, and results will be used to determine values for soil nutrient compartments of the hydrologic model.

Under the research project Development of Ecological Indicator Guilds for Land Management, Dr. Anthony Krzysik of Prescott College selected 40 research sites to represent the full range of upland habitats at Ft. Benning. At each site, field data were collected on the following ecological indicator guilds: (1) habitat characterization (physiognomy and soil physical properties); (2) ground cover (floristics); (3) ground ant communities; (4) microbial communities; (5) soil chemistry (including soil mineralization potential); and (6) developmental instability of the perennial forb, Tred-Softly (Cnidoscolus stimulosus). The 40 sites were classified into upland forest community types on the basis of tree species basal areas, using Hierarchical Agglomerative Cluster Analysis employing Ward's criterion and squared Euclidian distance as the similarity metric. Independently, Nonmetric Multidimensional Scaling ordination was also performed on the tree species basal area data to disclose potential environmental gradients in the research sites.

Under the research project Indicators of Ecological Change, Dr. Virginia Dale of Oak Ridge National Laboratory has calculated and analyzed the landscape metrics for Ft. Benning from historical data maps and remote sensing imagery. The research team evaluated the sensitivity of nationwide and regional bioassessment protocols. Together, analyses of relationships between bioassessment metrics and disturbance intensity within SEMP catchments will allow the team to evaluate the efficacy of a comprehensive set of protocols to indicate biotic impairment from sediment disturbance at Ft. Benning. An assessment was conducted on how roads can change the environmental conditions in which they occur at three spatial scales: a second-order catchment, a third-order watershed, and the entire military installation. At the finest resolution, total vegetation cover responded quickly to disturbance with a tracked vehicle, but there were differences in recovery between plant species. In examining roads within a watershed from 1974 to 1999, forest conversion was highest near unpaved roads and tanks trails. At the installation level, major roads and unpaved roads and tank trails were associated with most of the conversion from forest to non-forest.

Under the research project Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality, Mr. Charles Garten of Oak Ridge National Laboratory continued the investigation of thresholds associated with natural and/or anthropogenic disturbance that establish the potential recovery of soil quality on disturbed lands. The research team completed post-disturbance soil sampling at the K 11 study site and analysis is underway to determine total soil carbon and nitrogen concentrations. A summarization of measures of soil quality was completed for over 100 sites under perennial vegetation and at 20 sites where there has been recent soil disturbance at Ft. Benning. Model calculations indicate that a combination of desired future conditions, initial levels of soil quality (defined by soil carbon stocks), and the rate of biomass accumulation determines the predicted success of ecosystem recovery on disturbed soils. The team is in the process of estimating potential excess nitrogen (PEN) loading to streams on Ft. Benning by using an empirical, nutrient transport, hydrological model. The end products are spatial maps that show the calculation of total seasonal and annual loads of nitrogen to surface receiving waters at Ft. Benning.

Under the research project Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics, Dr. Beverly Collins of Savannah River Ecology Laboratory collected field data to compare biogeochemical cycling and vegetation between 2-yr burn sites (now in the second post-burn season) and 4-yr burn sites (now in the fourth post-burn season) on sandy and clayey soils in heavier and lighter military training compartments. Results indicate that sites with unique species composition tend to have burned four

times more since 1980 or are in heavier military use compartments. These sites are dominated by open-site, early successional, or fire-tolerant species.

As part of the SEMP Integration effort led by Dr. Virginia Dale, a questionnaire was provided to the research teams to nominate initial candidate indicators and review the candidate indicator evaluation criteria. This was the first stage of the overall SEMP integration effort. Each team responded with candidates, and some teams suggested minor revisions to the criteria lists. In subsequent phases, additional candidate indicators will be gathered, then evaluated against the indicator criteria list, and winnowed down to a small set of indicators that best fit the agreed upon criteria. A workshop was held at Ft. Benning to address the second aspect of the Integration plan. Ft. Benning staff identified land use types and land cover types and developed a comprehensive matrix of land use/land cover combinations. This workshop has resulted in a matrix that will be evaluated by the host site staff and the research team. Each relevant research site will be assigned to a specific land use/land cover type based upon location and status of the data collection site.

The ECMI team has been monitoring meteorology parameters at 10 sites since FY 1999. Coordination efforts with personnel at the Land Management Branch and Battle Lab at Ft. Benning continued to transition the meteorology monitoring from ECMI to the installation. Testing of the new sensor technology for surface and ground water monitoring is almost complete with results expected soon. Land cover maps from 1999 and 2001 were re-evaluated to compare the spread of urban areas around Ft. Benning and the cantonment area. Land cover metrics have been developed for both maps using fragmentation statistical techniques. Data from the erosion deposition component have been analyzed and summarized to evaluate the balance between biotic and abiotic components of ECMI and to justify the erosion/deposition component. Ft. Benning's revised forest inventory procedure was implemented in FY 2003 and an initial analysis of woody productivity was conducted. Extensive data analyses on all ECMI data sets will be performed to determine if they are useful to the installation land management personnel and to evaluate the balance between biotic and abiotic components of the monitoring scheme.

The SEMP data repository was relocated to the Engineer Research and Development Center, Information Technology Laboratory (ERDC-ITL) Web Farm. The Web Farm maintains the repository and provides any necessary hardware or software upgrades, security checks, and provides routine system maintenance as needed. Several modifications to the repository have been made including the adoption of .net framework technology, modernization of the user interface, and a more simplified and automated procedure for users to submit data to the site. The SEMP data depository web site was officially launched in April, 2003.

Numerous publications and presentations have resulted from these projects. More information on SEMP can be found on the website: www.cecer.army.mil/KD/SEMP

TRANSITION: The goal of SEMP is to provide knowledge, tools, and techniques to contribute to understanding and enhancement of the ecological role of military installations within their ecoregions. Project results and findings will be integrated into DoD ecosystem management policy and procedures to provide DoD land managers the necessary guidance and tools for a sustaining future military training and testing. The monitoring and research results will also be available to other Federal land managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Hyperspectral Techniques to Monitoring and Management of Invasive Weed Infestation; CS-1143

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Susan Ustin, University of California, Davis, CA

FY 2004 FUNDS: $250K

DESCRIPTION: The rapid spread of non native invasive plant species, including noxious weeds is causing irreparable damage to the natural resources on military installations. This project aims to develop and demonstrate a new remote sensing methodology using hyperspectral imaging (HSI), for mapping invasive weeds. Seven bases have been selected that have different weed types, intensities, and patterns of environmental disturbances from the southeast, southwest, and northwest ecoregions of the U.S. to demonstrate, refine and validate the proposed methodology. Appropriate airborne flightlines that include a range of types of weed problems on the base, intensity of invasive weeds, and encompass a range of land use conditions will be identified. These data will provide a basis for demonstrating and assessing the benefits of HSI data for mapping various species of weeds under the diverse conditions existing at each of these military bases. New support vector machine learning tools will be used to characterize the habitats and identify weeds in the HSI imagery. The Hierarchical Foreground Background Analysis (HFBA) is one example of a multi scale resolution analysis that is used to link the spectral variation for each pixel with variation in the spatial domain. The HFBA decomposition is coupled with a wavelet based, multi scale resolution in the spatial domain. This method addresses three issues (spectral redundancy, the span and completeness of a supervised classification, and a mechanism for producing an automatic classification) regarding spectral features which are not addressed by standard methods of image analysis. The combination of HSI tools for analysis of field spectra and images will provide a robust protocol for monitoring ecosystems that can be applied, even when the specifics of the location and the nature of the invasive species changes.

BENEFIT: The immediate benefit of this project will be a better understanding of the distribution of major invasive weeds on military bases and the environmental conditions associated with their distributions and spread. The long term benefit will be in developing a cost effective method for mapping weeds that can be used to monitor spread of weeds to new locations.

ACCOMPLISHMENTS: During the past four years field data has been collected at seven military bases to support Advanced Visible Infrared Imaging Spectrometer (AVIRIS) overflights. Differential Global Positioning System (DGPS) field data of the ecological conditions has been acquired at each of these sites to assess the types of conditions in which target weeds occurred at the sites. The research team has been successful in identifying target weeds (two per base) against the native vegetation background and have finalized the image analysis and validation of the weed maps for Vandenberg Air Force Base (VAFB), CA and Camp Pendleton, CA. A validation field campaign for the preliminary weed map at Ft. Benning, GA has been conducted. One of the primary findings has been that several standard HSI analysis methods produce good results at most bases and for most weeds. This suggests that military training can be standardized and that unique methods will not be required in most cases. A model was developed for VAFB using image results and GIS layers that will predict spread of invasive species (iceplant and pampas grass). Testing of the model is nearly complete and shows promising results. Additional bases will be analyzed using this model in the coming year.

TRANSITION: Demonstrations of the tools will be provided to site personnel and written technology transfer documents and a web based training course as part of the technology transfer objectives will be developed.

PROJECT SUMMARY

PROJECT TITLE & ID: Exotic Annual Grasses in Western Rangelands: Predicting Resistance and Resilience of Native Ecosystems Invasion; CS-1144

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jayne Belnap, U.S. Geological Survey, Canyonlands Field Station, Moab, UT

FY 2003 COMPLETED PROJECT

DESCRIPTION: This project examined what controls a system's susceptibility to invasive species. While physical disturbance appears to play a role, many disturbed areas are not invaded, while many undisturbed areas have been invaded. This project proposed to (1) determine if the current distribution of cheatgrass (*Bromus tectorum* - an invasive species) and other annual grasses could be predicted on a landscape and regional level using soil chemistry; (2) construct a model that predicts which soils are resistant or susceptible to annual grass invasion for a large watershed; (3) investigate positive feedback loops that may perpetuate annual grass dominance, such as altered soil organic matter, litter, or chemistry; and (4) examine ways to favor native plant re-invasion by altering soil chemistry.

The initial focus was the random selection and sampling of sites. These sites represented major habitat types (based on vegetation and soil types). At each site, slope, aspect, elevation, soil type, past and present anthropogenic disturbance and distance to roads were noted. Cover of vascular and non vascular vegetation was estimated. Soil depth and stability were assessed along with chemical properties. Soil food webs were analyzed as well. Magnetic properties, which indicate the presence of windblown dust, were measured. Regression analyses were conducted to see what factors best predict the presence of *Bromus*.

BENEFIT: This project will aid installation managers in predicting what soils are susceptible to invasive species and facilitate re-establishment of lost habitat. In addition, understanding how annual grass invasion changes natural ecosystem processes, such as nutrient availability, water availability, and soil microbial systems and how these changes affect re-establishment of native perennial plants, will enhance efforts to restore lost habitat. Specifically, the information resulting from this project will help prevent *Bromus* invasion, and therefore, sustain valuable military training and testing lands.

ACCOMPLISHMENTS: Using landscape assessments, vegetation and soil chemistry "fingerprints" of invaded and non-invaded areas of *Bromus*, helped determine habitats vulnerable to invasion. Results indicated that the invasion of *Bromus*, in the absence of grazing and fire, did not negatively impact the native perennial grasses *Stipa hymenoides*, *Stipa comata*, *Sporobolus airoides*, or *Hilaria jamesii*. Native soil biota was profoundly affected by the presence of *Bromus*, and many species present in the native community were not found in *Bromus*-dominated communities. Native soil biota and nutrient cycles were very different in *Bromus*-dominated soils, allowing native plants to successfully grow in these soils. As a result, restorations of *Bromus*-dominated areas do not require restoration of soil biota. A conceptual model developed to predict soil susceptibility to annual grass invasion was found to vary with climate regimes. In hot deserts (e.g., Mojave) where winter rains dominate, soils with low to medium phosphorus availability do not appear invadable. In hot deserts where summer rains dominate, the only invaded soils are those with high phosphorus availability. As winter rainfall amounts increase going northward, phosphorus is no longer limiting; instead potassium or nitrogen becomes the limiting factors.

TRANSITION: The project results will have an impact on directing the specific management actions relative to *Bromus* invasion including methods to control *Bromus* while enhancing the growth of native species.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Control and Assessment of Knapweed and Cheatgrass on Department of Defense (DoD) Installations; CS-1145

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Paschke, Colorado State University, Ft. Collins, CO

FY 2004 FUNDS: $187K

DESCRIPTION: The objective of the project is to develop a strategy for the control, monitoring and prediction of knapweed and cheatgrass infestations at two military installations in the Western U.S. The technical approach evaluates the combined effects of (1) biological control using insect pathogens, (2) fire, (3) manipulation of soil N availability, (4) seeding with native late seral species, and (5) restoration of the soil community. A replicated partial factorial arrangement of test plots in established communities of cheatgrass and knapweed are being used. The results of these manipulations on plant community composition will be monitored over a four year period in order to evaluate success. Results from our study will be incorporated into an existing ecological dynamics simulation (EDYS) model. The EDYS model will be calibrated to each of the field study sites to assess the direct and indirect effects of treatments on ecosystem dynamics at multiple spatial scales, and to project potential effects of treatments on long term successional dynamics. Remote sensing methods will be used to test the effectiveness of these methods for monitoring population densities of weed species over a large area.

BENEFIT: This project will provide a new effective methodology for controlling non indigenous invasive plant species. The overall long term benefit will be reduction of knapweed and cheatgrass populations on military installations and other lands, and a return of native plant communities to provide more realistic training areas and thus improve mission readiness.

ACCOMPLISHMENTS: Research plots were established at Ft. Carson (FC), CO, and Yakima Training Center (YTC), WA, and experimental treatments for the control of annual brome and knapweed were initiated immediately following baseline data collection. These treatments included release of insect biocontrol agents for knapweed, burning of annual brome stands, seeding with desirable plant species, control of soil N availability, and introduction of late-successional soil communities. Post-treatment data have been collected for each of the 160 research plots to include: plant community biomass composition, soil fungal community assessment, soil nitrogen availability, and knapweed biocontrol population assessments. Populations of insect biological control agents released in 2000 have become established in the plots (*Larinus minutus* at YTC and *Cyphocleonus achates* at FC). The spread of biocontrol agents to the control plots at YTC has prompted the use of systemic insecticide on knapweed plants to provide a true control treatment. The effectiveness of sucrose amendment treatments to reduce soil nitrogen availability was demonstrated using in situ ion-exchange resin bags. The DOE Remote Sensing Lab has completed remote sensing tasks of research plots at YTC. The EDYS model has been implemented and calibrated for the test sites at the two military installations using both existing information and the plot-specific data collected in 2000, 2001 and 2002.

TRANSITION: Resulting methodology for controlling these weeds will be made available to others through peer reviewed journal articles, web pages, and presentations at scientific meetings and symposia. The project results will directly serve to facilitate current management actions at military installations.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Monitoring of Threatened and Endangered Species in Inaccessible Areas; CS-1185

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kurt Fristrup, Cornell University, Ithaca, NY

FY 2003 COMPLETED PROJECT

DESCRIPTION: Large parcels of known or suspected threatened and endangered species (TES) habitat are in areas inaccessible to ground personnel because of operational restrictions or unexploded ordnance. Because biologists are unable to use traditional ground based survey methods in these areas, this project developed an airborne monitoring system for taking censuses of acoustically active species from the air.

The monitoring system consisted of three components: (1) a microprocessor controlled digital data recording system that can be deployed either on the ground or on an airborne platform; (2) a helium filled lift vehicle that can carry the recording system aloft for drifting or tethered deployments; and (3) a software package for automatic extraction, identification, and localization of sounds of interest. All three components represent plausible extensions of technologies that have been successfully implemented by the Cornell Bioacoustics Research Program and its affiliates. The completed system enables long term or wide area acoustic monitoring, with fully automatic data reduction. Post deployment processing is capable of producing a map of sound source locations and a log of species and time of call for all detections of interest. Summary statistics regarding call density, the estimated density of animals, and measures of the uncertainty of these estimates have been produced. Fully functional systems were provided to Ft. Hood, Texas, for surveys of golden cheeked warbler (GCWA), black capped vireo (BCVI), and least Bell's vireo.

BENEFIT: This project resulted in the deployment of a fielded system that enables natural resource managers at Ft. Hood to obtain data on the presence and distribution of the endangered GCWA and BCVI within the 60,000 acre live fire area. Such data have previously been either sparse or non existent because of access restrictions to this area. In the long term, application of the tools that were developed in this project should reduce the cost and operational impact of conducting biological surveys in areas where such surveys interfere with military operations. The resulting data will support the development and implementation of management plans to protect TES and their habitats while minimizing impacts on the military mission.

ACCOMPLISHMENTS: The project successfully developed an autonomous recording unit (ARU) that can be deployed for weeks or months at a time to monitor GCWA and BCVI populations. An airborne balloon platform was developed to transport the ARU in order to perform aerial acoustic monitoring. The balloon system maintains a set altitude (typically between 100 and 400m) by venting helium or dropping ballast and drifts passively with the wind. An onboard Global Positioning System (GPS) module logs the balloon's track. Throughout the balloon's flight, a digital storage module records signals from a microphone mounted in a trumpet-like horn. The horn amplifies sounds in the frequency band of interest. Statistical models were produced that relate balloon drift rates to the probability of a bird singing while the balloon is in range. Ground-based ARUs have collected more than 10,000 hours of BCVI and GCWA recordings from 50 sites at Ft. Hood, TX. Prototype software and software packages have been developed that automatically detect songs of BCVI and GCWA and interactively review their results in both Java and Matlab. Both the aerial and ground-based acoustic listening systems can be used to track other acoustically active animals.

TRANSITION: The equipment and methods to be developed in this project will be applicable to monitoring acoustically active TES that occur at other DoD installations, such as the red cockaded woodpecker (Ft. Bragg, NC; Ft. Benning, GA; Ft. Stewart, GA), Mexican spotted owl (Ft. Huachuca, AZ), and least Bell's vireo (Camp Pendleton, CA).

PROJECT SUMMARY

PROJECT TITLE & ID: Riparian Ecosystem Management at Military Installations: Determination of Impacts and Restoration and Enhancement Strategies; CS-1186

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Patrick Mulholland, Oak Ridge National Laboratory, Oak Ridge, TN

FY 2004 FUNDS: $446K

DESCRIPTION: To help DoD better balance land stewardship with its training missions, this project is designed to increase understanding of riparian functions and stresses, and the ecological effects of specific riparian restoration strategies. Two objectives will be addressed: (1) the identification of impacts of upland (erosion) and riparian disturbances (denudation, fire) on riparian functions; and (2) the evaluation of the effects of riparian restoration involving woody debris additions and revegetation to channels. Impacts of current stresses on riparian functions will be based on measurements and comparison of these measurements in catchments at Ft. Benning, Georgia. Both reference catchments and disturbed catchments that represent a range of disturbed conditions will be monitored and characterized. Riparian and stream characteristics and processes will be quantified in each catchment. Soil and vegetation measurements will be used to define riparian processes. Stream measurements include hydrologic, nutrient and sediment concentrations, metabolic, and periphyton and macroinvertebrate communities. The restoration phase of this project involves woody debris additions in ephemeral channels and 1st/2nd order streams of highly disturbed catchments. Revegetation, using native grasses and woody vegetation, will be conducted in highly disturbed ephemeral channels. The efficacy of the two riparian management restoration strategies (i.e., woody debris additions, and revegetation) to relieve stresses and improve riparian ecosystem functioning will be evaluated.

BENEFIT: The long term benefit of this project is an increased understanding of riparian ecosystem functions, how military training activities can impact those functions, and how land management activities at military bases can be designed to reduce or eliminate these impacts. The results of this research will provide managers with the information needed to make better land management decisions and more effective restoration plans that can sustain military base ecosystems and the training missions they support.

ACCOMPLISHMENTS: Measurements to assess the effects of military training disturbances across a gradient of disturbance levels in 10 small catchments drained by 1st to 2nd order streams have been completed. Preliminary analyses indicate the following disturbance impacts: (1) high sedimentation rates in ephemeral drainages leading to reductions in fine root biomass, litterfall, annual wood increment and aboveground biomass of vegetation; (2) increases in inorganic suspended sediments but declines in soluble reactive phosphorus and dissolved organic carbon concentrations in streams under baseflow conditions; (3) larger increases in concentrations of inorganic and organic suspended sediments, particulate phosphorus, and nitrate in streams under stormflow conditions; (4) declines in coarse woody debris and benthic organic matter in streams; (5) declines in total respiration and gross primary production in streams during some seasons; (6) declines in macroinvertebrate biomass and number of taxa and taxa in streams during some seasons; (7) declines in algal biomass and the percentage of sedimentation tolerant taxa; and (8) declines in the number of fish species during spring. These data and analyses will also comprise the pre-restoration data with which to evaluate pilot riparian and in-stream restorations.

TRANSITION: This project will provide prioritized and simplified riparian assessment metrics and protocols which can be used to facilitate the development of riparian restoration and adaptive management support tools for land managers and military trainers. Project results will be integrated into SERDP's Ecosystem Management Project (CS-1114), a long-term monitoring and research initiative at Ft. Benning.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag; CS-1188

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Tyack, Woods Hole Oceanographic Institute, Woods Hole, MA

FY 2004 FUNDS: $350K

DESCRIPTION: This project will quantify the probability of passive detection of marine mammals in Navy range waters which is currently hindered by an absence of information regarding the vocalization rate, level, and spectral characteristics for many marine mammals found in Navy range waters, especially deep diving whales. The second objective is to evaluate the short and long term impacts of Defense activities on marine mammals. Woods Hole Oceanographic Institution (WHOI) has developed a miniature digital acoustic tag (DTAG), that provides high fidelity, on animal recordings of vocalizations and ambient sound. The tag also includes orientation and dive sensors, and provides a uniquely direct means for establishing the behavioral response of a whale to an impinging sound. This project will perform a series of field experiments combining surface observations with on whale recordings using the DTAG. Focal follows of tagged animals will produce a database of vocalizations from whales with identified species and behavior. These data will be used to estimate vocalization rates. The second experiment involves simultaneous recordings of vocalizations at a tagged animal and at range hydrophones. The result will be a set of reference recordings from animals of known position and species, which can be used to evaluate, and enhance, passive detection, localization, and classification algorithms. Finally, controlled exposures of Navy related sounds will be made to tagged animals to determine if, and under what conditions, deep diving whales react to man made sounds.

BENEFIT: The project research on short term impacts of naval sound sources will provide critical data for developing protocols for operating these sources in ways that comply with federal environmental laws. Without this information, there is a risk either that these sounds may adversely impact protected populations or that protective measures taken as a precautionary measure because of ignorance may impact naval operations. Once passive acoustic monitoring has been tested and validated, it offers a non invasive, cost effective method to monitor vocal behavior and distribution of vocalizing animals.

ACCOMPLISHMENTS: The most significant achievement during the past three years has been a steady development of tagging methods. The team has succeeded in attaching a tag for 17 minutes which led to a major redesign of the tag, making it much smaller and more capable of recording high frequencies. This redesigned tag proved extremely well suited to tagging beaked whales, with between 3 and 34 hour attachments on the two species of most concern for mass stranding, Cuvier's Beaked Whale (Ziphius cavirostris) and Blainsville's Beaked Whale (Mesoplodon densirostris). Data collected from the tagged whale clicks at depths below 500 meters identifies their vocal behavior. They have been shown to dive for 80 minutes to a depth of 1200 meters and show a click-creak-rest pattern when foraging that is similar to sperm whales. Both the dive and vocal data are critical for understanding risk factors for beaked whales and mid-frequency sonars. The ability to specify the vocalizations of these beaked whales opens the possibility of developing systems for passive acoustic detection. This is important for monitoring and mitigation of potential impacts of noise on navy ranges and during naval exercises.

TRANSITION: The results of this project will transition into the Navy's marine mammal protection program. The data will provide vocalization databases required to assess the probability of detecting animals on Navy ranges. In addition, the team will work with range acousticians and signal processors to provide a biological perspective.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic and Visual Monitoring for Marine Mammals at the Navy's Southern California Off Shore Range; CS-1189

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Hildebrand, University of California-San Diego, La Jolla, CA

FY 2004 FUNDS: $340K

DESCRIPTION: The Southern California Off Shore Range (SCORE) is a region where naval operations are frequently conducted and where marine mammals are known to be abundant. The technical objective of this project is to compare methods for actively monitoring marine mammals within the SCORE region using the following four techniques: (a) Aerial surveys (visual), (b) Ship based transect surveys (visual), (c) Sonobuoy based mobile acoustic surveys, and (d) Continuous fixed site acoustic surveys.

Simultaneous application of these techniques will allow their comparison to determine the combination of methods most suitable for long term monitoring of the SCORE range. In addition, this project will investigate the contribution of environmental factors, such as sea surface temperature, to make an environmentally based model for marine mammal presence. This research will allow for better understanding of marine mammal presence within SCORE and improve techniques for studying marine mammal presence at other sites of naval interest.

BENEFIT: There is a high priority Navy requirement for data on marine mammal locations and seasonal densities within areas of frequent naval operations. The acoustic population estimation techniques developed by this project offer the potential for efficient and economical monitoring of marine mammals. These techniques are a first step in understanding the impact of sound on marine mammal behavior. This is an area of intense research by the Office of Naval Research and the Chief of Naval Operations (N45) with respect to environmental compliance issues.

ACCOMPLISHMENTS: Blue, fin, and humpback whales, as well as several species of odontocetes and delphinids, have been studied in the SCORE region, and acoustic data have been processed for marine mammal calls using automated call detection algorithms. Blue whale seasonal presence has been determined from their calling that begins in early June, peaks from August through October, and decreases through the fall. A combination of aerial survey data and shipboard visual survey data suggests that there is a mismatch in the seasonality of blue whales detected visually and those detected acoustically. More whales are visually detected early in the summer, while acoustic detections peak late in the summer. In addition, a diurnal calling pattern has been observed with 30% more calls at dawn and dusk than at other times of the day. A recording acoustic tag has been developed in collaboration with Cascadia Research and Greeneridge Sciences. The tag has revealed blue, fin and humpback dive patterns and also behavior during the production of acoustic calls. From the combined tagging and biopsy effort, results indicate that nearly equal numbers of male and female whales are present within SCORE.

TRANSITION: Research findings will transition for use by SCORE personnel as a real time system for marine mammal detection and classification, as a database of seasonal marine mammal presence within SCORE, and as a predictive model for marine mammal association with environmental conditions. Marine mammal density estimates, as a function of both time and location as produced by this project will be integrated into a planning tool for use by the Navy. Development of acoustic techniques for marine mammal population assessment will also transition into the larger marine mammal science community. Passive acoustic monitoring can be applied as a complimentary technique to traditional visual survey such as those conducted by the National Marine Fisheries Service (NOAA Fisheries).

PROJECT SUMMARY

PROJECT TITLE & ID: The Evolving Urban Community and Military Installations: A Dynamic Spatial Decision Support System for Sustainable Military Communities; CS-1257

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Deal, University of Illinois, Champaign, IL

FY 2004 FUNDS: $450K

DESCRIPTION: Extreme urban growth and the resultant patterns of development outside military installations are undermining the military community's ability to maintain mission focus. Some military installations economic and environmental contributions to the local community are becoming outweighed by perceived incompatibilities such as noise, dust, shared resource competition, land use, land value, and land availability. These arise as the local community expands and available resources become scarce.

This project will quantify the current and future impacts of urbanization on the operations and sustainment of military installations. A Spatial Decision Support System (SDSS) is used to identify the factors and variables that contribute to land use transformation and the subsequent conflicts that can arise between the military establishment and adjacent private sector communities due to conflicting land use goals. The SDSS includes the development of spatial, societal and environmental impact assessments. The creation of indicators of installation sustainability, using both mission and ecological oriented criteria, will be established. The SDSS will be applied to identify military installations most at risk from rapid exogenous urbanization.

BENEFIT: The military can benefit from better planning tools for predicting exogenous and endogenous land use needs and their conflicts with installation mission requirements. This project focuses on the development of a dynamic and military specific SDSS that will improve the decision making processes and land management practices of the military installations and adjacent private sector communities. The fundamental purpose of this work is the discernment of possible approaches to planning solutions that can help sustain the military missions and environments within the communities in which they exist.

ACCOMPLISHMENTS: Baseline data has been collected for a number of specific sites and a proof of concept has been completed. In addition, a visual interface for the national risk data has been collected. Work on the military Land Use Evolution and impact assessment Model (mLEAM) has proceeded in two areas - the development of an input/output economic engine for more detailed economic drivers and a habitat fragmentation model that will better describe changes to critical habitat due to urban transformation. Both are now being included into the broader model. An approach to tackle socially related drivers and impact factors have also been developed. Coordination continues with other SERDP funded projects on the development of an uncertainty calculation and variable weighting measures.

Other dynamic simulation work is geared toward the development of a standardized, quick application model that can more rapidly assess regional encroachment stress. Test applications have been made to Ft. Bragg, NC; Camp Ripley, MN; and Ft. Carson, CO. A more detailed application of the current mLEAM model is being developed for Ft. Benning, GA.

TRANSITION: The outcome of this project will provide MACOMs with an analytical and visually oriented methodology for determining where the threat of urban growth might negatively impact the military mission, how this threat will impact military operations, and possible strategies for mitigating these impacts.

PROJECT SUMMARY

PROJECT TITLE & ID: RSim-A Regional Simulation to Explore Impacts of Resource Use and Constraints; CS-1259

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Virginia Dale, Oak Ridge National Laboratory, Oak Ridge, TN

F**Y 2004 FUNDS:** $512K

DESCRIPTION: The need for applying ecosystem management approaches to military lands and regions that contain them is critical because of the unique resources on these lands and the fact that conservation issues may jeopardize military missions if not appropriately managed. This project will address this critical need by enabling application of ecosystem management approaches to military lands and surrounding regions. The objective is to develop a spatially explicit simulation model that will enhance the abilities of military planners to understand the implications of external land use change, resource use and future development policy on the sustainability of military land and missions.

A Regional Simulation Model (RSim) will be designed to integrate environmental effects of on base training and testing and off base development and other decision. Effects to be considered include changes in air and water quality, noise conditions, and habitats for threatened and endangered species and game species. The simulation environment will build upon on existing land use change model and will be designed to be available to users via a web interface. The model will be provided in a gaming mode so that users can learn about the potential environmental repercussions of military and land use decisions. The RSim model will be developed and applied to the region around Ft. Benning, GA, because of the large amount of data available for the installation and surrounding region and the cooperation offered by the installation in developing and testing the model. However, the model will be designed so that is broadly applicable to DoD's environmental management concerns. A risk assessment approach will be used to determine impacts of and integrated risks.

BENEFIT: The simulation tool will be of general applicability to land owners and managers but will be of special interest to military planners at DoD installations. The approach will allow consideration of several criteria at the same time including air, water, noise and species. Acceptable land uses will be those that maintain standards within all of these categories.

ACCOMPLISHMENTS: RSim is being designed to project land-use changes and its impacts for the five counties in Georgia surrounding Ft. Benning. Two growth scenarios have been implemented. The urban growth submodel in RSim consists of spontaneous growth of new urban areas, patch growth (growth of preexisting urban patches). The road-influenced urbanization submodel focuses growth on areas near existing and new roads by considering the proximity of major roads to newly urbanized areas. Projections show that urban growth will continue along the northern border of Ft. Benning and may have impacts on noise, water, and air quality. Effects of urban growth on existing populations of endangered red cockaded woodpecker and gopher tortoise are not anticipated.

TRANSITION: At the completion of this project, land managers and planners will be able to use this user friendly tool at Ft. Benning to help understand the implications of external land use change, resource use and future development policy on the sustainability of military land and missions. Transition of this tool to other installations is dependent on the type and amount of data available in and around an installation, however, the methodology will remain relatively the same.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Identification of Archaeological Sites and Features Using Radar Data; CS-1260

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Blom, NASA/Jet Propulsion Laboratory, Pasadena, CA

FY 2004 FUNDS: $100K

DESCRIPTION: Application of aerial and satellite radar data for archaeological inventory and evaluation has been limited for two reasons: (1) most cultural features are too small to be identifiable given the resolution of imagery produced from the radar data using current processing and post processing protocols, and (2) until recently, imaging radar data have been only collected at a single frequency/polarization combination. This project will identify the radar wavelengths, polarizations, and angles of transmittal that are most effective in detecting and characterizing a variety of archaeological sites and features under conditions that fall within environmental parameters common to much of the western U.S. Airborne radar data will be collected with a multi band, National Aeronautics and Space Administration (NASA)/Jet Propulsion Laboratory (JPL) multi polar radar instrument (Airborne Synthetic Aperture Radar [AIRSAR]) over San Clemente Island, CA. The resulting understanding of the behavior of radar in response to archaeological targets will provide the basis for the formulation of effective, transferable protocols for detection and evaluation of cultural resources on military installations in the western U.S.

BENEFIT: The protocols developed by this research will demonstrate and prove the utility of synthetic aperture radar to finding and evaluating archaeological sites. Those most readily identified by the refined technologies and protocols will be among the most important and challenging from a cultural resource management point of view: structural sites, sites with middens, and sites that have been occupied over an extended period of time or reoccupied repeatedly with the result of altering soils chemistry and vegetative pattern. Processes for radar bands and polarizations will be much better understood so that they can be better applied to finding and characterizing archaeological sites. The protocols will be in effect produce a pilot scale system for this application of synthetic radar technology to cultural resource management.

ACCOMPLISHMENTS: New image processing and post-processing procedures have been developed for AIRSAR data that render images produced useful for inventory and evaluation of small scale resources. Data for which this has been done include P-, L-, and C-bands in both Polarimetric AIRSAR (POLSAR) (full polarization for all bands) and Topographic Synthetic Aperature Rador (TOPSAR) (digital elevation model (DEM) production) modes. Procedures to orthorectify images for all polarizations of C-band data have been developed, which has necessitated the development of algorithms for using the DEM produced in TOPSAR mode to orthorectify images generated from TOPSAR data. Slope and hydrology information has improved models that will be used in developing signatures for archaeological sites. Signature development is also being advanced by algorithms that will co-register P-band imagery to L- and C- band imagery more precisely than has ever been done. Mosaicked radar images have been produced from multiple flight lines that display reduced speckle noise (caused by random interaction of radar returns) and minimize slope effects on backscatter. Finally, in regard to signature development, post- processing protocols have been devised that not only further reduce speckle, but also enhance backscatter so that locations of the majority of archaeological sites with precise coordinates are highlighted. True signatures, which would exclude from consideration other areas of bright return, will be developed by a knowledge based classification protocol.

TRANSITION: If successful, the protocols developed will be transitioned to cultural resource managers to inventory archaeological sites in environments similar to those of San Clemente Island. Preliminary characterization of detected sites is also feasible. The next step in transitioning the technology is to modify the protocols for more heavily vegetated areas.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing an Efficient and Cost Effective Ground Penetrating Radar Field Methodology for Subsurface Exploration and Mapping of Cultural Resources on Public Lands; CS-1261

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Conyers, University of Denver, Denver, CO

FY 2003 COMPLETED PROJECT

DESCRIPTION: Military installations are in need of an efficient, accurate and readily useable method for discovery, mapping and possible avoidance of cultural resources in order to sustain military readiness. To date, no near surface geophysical method has been shown to be fully effective in the discovery of buried cultural remains. Ground penetrating radar (GPR) has recently proven to be very efficient at collecting data of buried objects in grids ranging up to 50x50 meters. This project quantified and calibrated GPR for known archaeological features commonly found in many areas of the U.S. in order to make GPR a more exact and easy to use tool for the discovery and mapping of buried and invisible sites. GPR data was collected at two facilities (the controlled archaeological test site (CATS) in Illinois, and the Hammer GPR site at the Hanford Reservation in Washington) using many different radar configurations. The data from the various radar configurations and environmental conditions was used to discover optimum GPR collection and processing methods. These data were compared to what is known about local conditions and the depth and composition of buried features. The final product is a field and laboratory protocol that can be modified depending on the ground conditions encountered, and the depth and aerial extent of the target features.

BENEFIT: This project developed and refined the use of GPR technology in archeology that will be central to the design and implementation of future GPR studies in cultural resource assessment. The results include a pre data acquisition protocol for site analysis, which will allow researchers to predict conditions expected in the field and to adjust hardware and software configurations accordingly. Site analysis of this sort will promote both an understanding of GPR energy radiation and reflection in the ground and save money and time as conditions can be predicted and adjusted for in advance.

ACCOMPLISHMENTS: GPR collection and processing techniques have been tested at two simulated archaeological sites in order to determine what methods are best for finding and mapping buried cultural remains. The CATS site is located in moist clay, while the Hammer GPR site is in dry sand. These two areas lie on either end of a spectrum of soil conditions usually encountered in the U.S. It was found that high frequency antennas that collect reflection data in very closely spaced transects provide the best subsurface resolution. Laboratory analyses of the soil samples at each site indicate that water in the ground is the dominant factor in determining the amplitude of the reflected waves. Some buried features were best imaged when conditions were wet and others when the ground was dry. In all cases the way that water was distributed on and within the targets seems to be the dominating condition. For instance buried wood was invisible to GPR when the ground was dry, as it did not contrast enough with the surrounding dry sand. But when it was wet, it contrasted greatly, and produced very strong reflections. This, and many other conditions were documented and quantified at the two test sites. All data collection and processing steps were synthesized into an over all GPR protocol for reference so that future researchers can choose the most advantageous equipment and processing programs for the conditions at hand.

TRANSITION: A quantitative analysis of GPR reflections during differing conditions, allows for the production of a protocol for GPR data collection on DOE and DoD lands. The protocol can then be used by cultural resource managers for GPR mapping, producing accurate maps of buried cultural sites, quickly and accurately.

PROJECT SUMMARY

PROJECT TITLE & ID: Methods for Assessing the Impact of Fog Oil on Availability, Palatability, and Food Quality of Relevant Life Stages of Insect Food Sources for TES, CS-1262

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dennis Strenge, Pacific Northwest National Laboratory, Richland, WA

FY 2003 COMPLETING PROJECT

DESCRIPTION: To comply with the Endangered Species Act, the impact of fog oil releases on avian threatened and endangered species (TES) (or surrogates) have been evaluated in both field and laboratory studies. Although no direct acute effects on avian species have been observed, concern has been raised regarding a possible indirect impact via reduction in insect populations used as a food source for these species. This concern arises from the fact that petroleum oils of similar composition to that of fog oil have long been used to kill insect pests. These oils particularly target soft-bodied insects, eggs and larvae, and flying adult forms that are important dietary components of several avian and bat TES inhabiting military lands. This project investigated the impact of wind speed and canopy structure (key factors identified in past fog oil deposition research) on fog oil deposition and insect toxicity and behavior through the use of wind tunnel tests providing reproducible exposures, which are difficult to obtain in field tests. The impact of fog oil on insects based both on quantity and quality of food source for endangered birds and bats was measured. The final product of this project is a set of response functions describing mortality, morbidity, food quality and food availability of insect prey of TES in terms of oil deposition rate, average air concentration, wind speed during generations, and canopy structure.

BENEFIT: The study will provide a cost-effective method, as compared to field assessments, for quantifying the potential impact of fog oil on the food base of TES inhabiting DoD lands where training activities are conducted. This will allow testing of prey species under relevant climatic and canopy conditions of specific TES. Because information on the effects of fog oil on important prey species of the red-cockaded woodpecker, several neotropical birds, and two endangered bat species are tested in this project, the exposure-response data from the study will directly benefit risk assessment/management efforts for these species.

ACCOMPLISHMENTS: The impacts of fog oil exposure on five species of insects representative of major prey groups of TES species of bats and birds that inhabit military lands were examined. Although the life stages of two species (wood roaches and beetles) displayed low susceptibility to fog oil toxicity, the remaining species (mosquitoes, ants, and moths) appeared to be sensitive to the obscurant at field relevant concentrations. The affect of environmental conditions on this susceptibility were examined and algorithms developed to describe the relationship between the condition (wind speed, canopy) and the toxic response. Remaining tasks include assessment of the impact of fog oil on flight characteristics of insects, and the impact on palatability of insects to birds.

TRANSITION: The information gained from this project will be used by installation managers to make decisions about the application of fog oil during training exercises. The set of response functions describing the mortality, morbidity, food quality, and food availability of insect prey of TES in terms of fog oil deposition rate, average air concentration, wind speed during generations, and canopy structure provide the means to establish appropriate protocols for using fog oil and protection of TES species.

PROJECT SUMMARY

PROJECT TITLE & ID: New Approaches to the Use and Integration of Multi-Sensor Remote Sensing for Historic Resources Identification and Evaluation; CS-1263

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Frederick Limp, University of Arkansas, Fayetteville, AR

FY 2004 FUNDS: $412K

DESCRIPTION: This project will focus on the development of powerful new analytical approaches that demonstrate the effectiveness of non-invasive archaeological methods and the deployment of tools that offer an opportunity to recover a great deal of information about site content while reducing costs associated with traditional archaeological survey and excavation. Exploration and assessment of the benefits of combining a large suite of ground, aerial and space-based sensor data for the detection of subsurface archaeological features is central to this research. State-of-the-art remotely sensed data will be acquired at DoD installations Ft. Bliss, TX; Ft. Benning, GA; Ft. Riley, KS; and at the DOE Savannah River Site, GA. New and existing data from these installations will be complemented with existing site data from two additional locations, Whistling Elk (SD) and Mt. Comfort (AR). These properties, selected based on cultural resource inventory, physical conditions (soils, vegetation), and degree of recent disturbance, contain a wide variety of archaeological sites in various natural environments. Remotely sensed data will be analyzed individually and in combination via a variety of innovative data fusion approaches, to make predictions about the nature of buried historic resources. A program of archaeological field-testing will be undertaken to validate predictions made during the data analysis phase.

BENEFIT: The results of this research program will: (1) generate knowledge about the predictive effectiveness of sensors individually and together; (2) describe the nature of the similarities, differences, redundancies, and performance characteristics of the sensors; (3) provide a cost-benefit analysis; (4) identify the kinds of archaeological features that may be detected with each method or combination of methods under various environmental conditions; and (5) recommend enhancements to current GPR technologies for archaeological applications. The project will additionally develop a digital soils data model that will allow installation managers to predict the potential usability of sensors at various locations on their properties.

ACCOMPLISHMENTS: High resolution ground-based geophysical data, satellite data and aerial data has been collected at the four study locations: Ft. Riley, Ft. Bliss, Ft. Benning and Savanna River DOE Site. Data include (1) resistivity, (2) magnetometry, (3) ground-penetrating radar, (4) conductivity, (5) magnetic susceptibility, (6) thermal, (7) aerial photography and (8) multispectral imagery. All geophysical data have been preprocessed as has a majority of the thermal and multispectral. Initial analysis has been completed on the Ft. Riley, Ft. Bliss and Ft. Benning data. Preliminary numerical data fusion has begun with Ft. Riley and Ft. Bliss data sets and early object fusion methods are underway. Very high quality results have already been produced from the Ft. Riley data and are expected from other sites as analysis proceeds.

TRANSITION: The transition will be designed to provide installation staff and technical specialists in the remote sensing community with information on the effectiveness of the systems and appropriate field implementation strategies. Two key vehicles for dissemination of the results will be through the North American Database of Archaeological Geophysics (NADAG, http://www.cast.uark.edu/nadag/) and through the project linkages to the private sector as provided by the participation of SRI and Geoscan Research. It is anticipated that instrument designers and software developers will respond and create products that can be used in future applications at installations and other locations. The aspects of the project that are expected to transition under this include data fusion software system based on SRI's model and rule bases for eCognition use.

PROJECT SUMMARY

PROJECT TITLE & ID: Impacts of Military Training and Land Management on Threatened and Endangered Species in the Southeastern Fall Line/Sandhills Community; CS-1302

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rebecca Sharitz, DOE Savannah River Ecology Laboratory, Aiken, SC

FY 2004 FUNDS: $259.1K

DESCRIPTION: The goal of this research is to develop methods to evaluate effects of military training and land management activities on the sustainability of fall line sandhills habitats and their threatened and endangered species (TES) on military lands in the southeastern U.S. This project will also provide recommendations for adaptive management to optimize land management decisions. Numerous military installations from all services share some or most of this sandhills species assemblage. Management for sustainable sandhills TES habitat would enable DoD and other land managers to address multiple TES simultaneously; however, military training activities and forest management for longleaf pine woodlands are potential threats to the sandhills ecosystem.

Geographic information systems (GIS) and spatially explicit models (SEMs) are used to develop a more comprehensive understanding of the potential impacts that military training and forest management practices may have on TES in sandhills habitats. Specifically, the project will determine if the combinations of frequency and timing of burning, and of military use, that best promotes the sustainability of the sandhills habitat also provides suitable conditions for individual TES, such as gopher tortoise.

BENEFITS: Results of this research will provide land managers at military installations along the Fall Line ecoregion with information needed to make decisions concerning training intensity and forest management that more effectively protect sandhills communities and their TES, and concomitantly allow for continued military training.

ACCOMPLISHMENTS: Initial efforts have focused on discriminating Fall Line sandhills communities from surrounding pine woodlands and on surveys of selected TES plant and animal species. Spatial data layers were developed for three facilities (Ft. Benning, GA, Ft. Gordon, GA and the DOE Savannah River Site, GA) and used to select possible sandhills sites for field surveys related to effects of forest management and military training activities. A total of 43 sites were selected and sampled for vegetation and soil characteristics to determine field metrics for discriminating sandhills communities. Canopy tree species importance values were generated for each site and cluster analysis grouped the sites statistically. A combination of Duncan's Multiple Range Test and Non-metric Multidimensional Scaling ordination was used to identify discriminating characteristics and to determine significant differences among site groups with regard to canopy species importance, soil moisture and texture, and soil nutrient content. These analyses are providing metrics for distinguishing xeric sandhills communities and input to GIS layers that will be used in constructing landscape-level spatial models of sandhills under different forest management and military training intensities. Surveys of the selected plant TES species and of physical features of sandhills habitats with and without TES populations were conducted. In addition, surveys of gopher tortoise burrows at sites under various forest management conditions have been initiated. These data are being analyzed and will provide input to produce spatially-explicit habitat models of Fall Line sandhills TES species.

TRANSITION: Information and recommendations from this research will guide resource managers at Ft. Benning and Ft. Gordon in developing management plans for sandhills areas. The protocols and techniques are applicable to all federal lands in the Fall Line sandhills region.

PROJECT SUMMARY

PROJECT TITLE & ID: Regenerating Longleaf Pine on Hydric Soils: Short and Long Term Effects on Native Ground-Layer Vegetation; CS-1303

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joan Walker, U.S. Department of Agriculture, Forest Service, Asheville, SC

FY 2004 FUNDS: $84.4K

DESCRIPTION: The longleaf pine ecosystem on DoD and other public lands provides habitat for many rare plants and animals, including federally protected species. Restoring and rehabilitating longleaf pine communities is essential for maintaining the health of protected species. This project evaluates a range of site preparation methods that could be used to restore longleaf pine stands on sites that no longer have a natural seed source, and determine the effects of these methods on the extraordinarily diverse ground layers that occur on moist, poorly drained sites. The study will also describe the persistent and long term effects of plantation establishment. Immediate and short term effects of management treatments on ground layer vegetation, and on longleaf pine establishment and early growth will be evaluated with a controlled field experiment. Long term effects will be investigated by quantifying vegetation composition and structure in mature plantations, and relating current conditions to know treatment histories and to the vegetation in high quality natural areas.

BENEFITS: The results of this work will provide a scientific foundation to evaluate methods for managing longleaf pine and associated species on the landscape. The successful establishment of longleaf pine stands that provide habitat for threatened and endangered species on wet, poorly drained sites will provide managers with flexibility in simultaneously maintaining defense oriented training and fulfilling DoD obligations to preserve endangered species.

ACCOMPLISHMENTS: Measurements of pre-treatment environmental conditions for the field experiments are nearly complete. Chemical and physical attributes of soils have been measured. Results from an initial sampling were used to determine an adequate sample size for detecting changes following treatments (statistical power analysis). Complete baseline samples were then taken, prepared, and analyzed for soil texture, pH, organic matter, cation exchange capacity, base saturation, Mg, Ca, K, P, nitrate, ammonium, Mn, Zn, Fe, S, Bo, Cu. The study area soils are spodosols with a characteristic hardpan layer that may interfere with root penetration, and associated seedling survival. In preliminary analyses, the team detected enormous variation in depth to the spodic horizon within experimental units; in order to account for such variation as it might affect results, depth to this horizon was mapped throughout the experimental units. These results have been analyzed and are in preparation for publication. Pre-treatment vegetation sampling was completed. In spite of much reduced access into training sites, experimental site preparation treatments were successfully installed with the help of natural resource managers and range control personnel at Camp Lejeune, NC. Eleven of thirty proposed sites were sampled for the analysis of long-term effects of pine plantation establishment on wet soils. Associated soils are prepared for chemical and physical analyses. The research team and the natural resources management staff met at Camp Lejeune to review progress, including reviewing preliminary findings on soil properties, and to coordinate research activities for the coming year.

TRANSITION: Camp Lejeune managers and Forest Service researchers are full partners in this research. Information transfer will occur throughout the project with frequent site visits to discuss progress and observe results as they develop. Formal field tours will be conducted for Federal, State, and private land managers with similar management challenges. Upon completion, or if interim results warrant, site preparation methods will be modified through the annual silvicultural prescription process and the Integrated Natural Resources Management Plan (INRMP) revision (specifically Section 11.1).

PROJECT SUMMARY

PROJECT TITLE & ID: Toxicological Effects of Smokes and Obscurants on Aquatic Threatened and Endangered Species; CS-1332

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Cropek, U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory, Champaign, IL

FY 2004 FUNDS: $385.4K

DESCRIPTION: Preparation for possible battlefield conditions requires military training activities to use smokes and obscurants (S&O). Many threatened and endangered species (TES) co-inhabit training areas where S&O are released; therefore, the impact of S&O on the vitality and survivability of TES and their habitats, including aquatic ecosystems must be ascertained. This work will study the direct and indirect effects of actual field deposition of fog oil, graphite, CS (o chlorobenzylidene malononitrile), and two colored S&O on three phylogenetic classes of aquatic organisms including TE fish, their insect prey, and TE mussels. This will be done through field collection of S&O chemical deposition, field exposure of selected organisms, laboratory tests of S&O chemical deposition, and laboratory exposure of selected organisms. Data will be developed and obtained that will predict the impacts, effects, and mortality on relevant aquatic species from exposure to varying concentrations of S&O. In addition, the insect fish mussel, food predator life cycle host interrelationships will be examined and interpreted in the context of observed results.

BENEFITS: This work will develop and refine the approach and information to be used by the military and other organizations to contribute to the overall management of aquatic TES and their habitats. These data will influence S&O usage and TES management to ensure environmental security and protection of valued aquatic resources preventing impairment of critical military training activities. Research will be published to provide guidance for selection and use of S&O in the field for optimal environmental protection with minimal impact on troop readiness.

ACCOMPLISHMENTS: Three separate sampling events occurred throughout 2003 incorporating the effects of different weather and wind conditions on deposition of military smokes and obscurants onto aqueous surfaces. Tests have been performed using fog oil by itself, fog oil and graphite together, and green, yellow, and red smoke grenades. Toxic effects of deposited smoke constituents on aquatic species were monitored. Only fog oil demonstrated a short term toxic effect on *Daphnia*. Other species including northern frog tadpoles, fathead minnow fry, rainbow darters, and midges showed no negative short term effects. The deposition rates have been measured with respect to distance from the smoke release point. The fog oil deposition rate increases with time indicating effective accumulation at the aquatic surface. Analysis of fog oil deposition clearly shows a change in the chemical constituency after high temperature fogging. Deposited smoke grenade components also show pyrolytic by-products. Comparison of deposition media illustrate the benefits of water and heptane samples for collection of deposition in the long term, glass fiber filters for collection of deposition in the short term, and the inability of inert substrates to effectively collect any deposition of hydrocarbon oils.

TRANSITION: Information, data, and results of this effort will be made available to installation, major command, and headquarters biologists, natural resources managers, land managers, and decision makers, as well as to other federal and state agencies, including those regulatory entities which have jurisdiction or interest in the biological, chemical, and environmental parameters involved (e.g., TES, toxicity, air quality, water quality, pollution, health, etc). These results will show the degree of impacts and effects on actual insect prey of TES, relevant surrogate and actual threatened fish, and environmentally sensitive endangered benthic mollusks that may arise from using military S&O during field training.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of ROV-Based Video Technology to Complement Coral Reef Resource Mapping and Monitoring; CS-1333

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pamela Reid, University of Miami, Marine Geology and Geophysics, Miami, FL

FY 2004 FUNDS: $278K

DESCRIPTION: Recent declines in coral reefs across the globe underscore the need for new scientific tools to better understand ecological patterns and rates of change. Comprehensive assessment of the coral reef resources demands a hierarchical mapping strategy involving microscale to macroscale measurements. Of immediate interest to the DoD are types of changes within reef systems that can be monitored at the mesoscale scale. The objective of this research is to develop technology based on usage of a remotely operated vehicle (ROV) to increase the speed and repeatability with which reef plots can be mapped and inventoried. Specific objectives are to: (1) apply advanced two-dimensional (2D) digital video mosaicing techniques to construct georeferenced images of plots on a coral reef; (2) extract and validate ecological indices of reef condition from the video mosaics; and (3) determine the range of environmental conditions (e.g., turbidity) for effective operation. As a secondary objective, the research program will explore development of tools to automate and/or assist image classification. This will involve three-dimensional (3D) reconstruction of specific reef features from stereo video data, and high resolution multi spectral imaging.

BENEFITS: This research will lead to the development of efficient methods for coral reef mapping and monitoring. The ROV based mosaic technology offers numerous advantages over traditional, diver based video transects, producing single, plot scale, high resolution images that are georeferenced and undistorted. These georeferenced images can be easily integrated with other data sets using Geographic Information Systems (GIS) to inventory reefs under DoD purview. This is an essential component of the legally mandated environmental documentation necessary for conducting military operations and will provide decision makers with critical information necessary to maintain compliance with relevant statutes, regulations, and Executive Orders (EOs).

ACCOMPLISHMENTS: Development of a positioning system for the Phantom ROV, which integrates angle sensor measurements of pitch and roll, magnetic heading, and motion information extracted from video, was initiated. High-resolution color camera systems were purchased to replace the former gray-scale low-resolution image system, and assembly is underway of a multispectral still camera system that will be used for automated image analysis. Initial field operations were conducted at the U.S. Navy Atlantic Undersea Test and Evaluation Center at Andros Island, Bahamas. Low resolution, gray scale video sequences were collected and mosaiced in a target area which was marked and calibrated with a 3x3m grid. Diver-based reef surveys were conducted in tandem with the ROV operations. 103 individual corals from 7 different species were identified within the 3x3m test grid. Continued monitoring of the size, position and number of these colonies throughout the project will provide information concerning the growth, mortality, and settlement rates of corals within the test area.

TRANSITION: The transition plan is designed to be flexible and economically feasible. The capability to produce georeferenced 2-D mosaics and extract relevant ecological parameters from these mosaics will be demonstrated. In addition, specifications for a prototype modular monitoring system will be produced. The modular nature of the package will enable flexible implementation of the technology and increase the economic feasibility of reproduction.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis of Biophysical, Optical, and Genetic Diversity of DoD Coral Reef Communities Using Advanced Fluorescence and Molecular Biology Techniques; CS-1334

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Falkowski and Dr. Maxim Gorbunov, Rutgers University, New Brunswick, NJ

FY 2004 FUNDS: $334K

DESCRIPTION: DoD is required to assess the impact of military activity on coral reefs and their surrounding benthic communities. Documenting the environmental state of reef communities is critical to developing remediation strategies that can both reduce anthropogenic impact and distinguish between natural and anthropogenic stress. The development of advanced technologies for environmental monitoring of benthic communities under DoD jurisdiction requires an understanding of how different environmental factors affect the key elements of the ecosystems and the selection of specific monitoring protocols that are most appropriate for the identification and quantification of particular stresses. Specific objectives of this study are: (1) to develop advanced techniques for rapid and non destructive assessment of the viability and health of coral reef communities with the capabilities of identification and quantification of natural and anthropogenic stresses; (2) to develop prototypes of Fast Repetition Rate (FRR) Fluorosensors for permanent underwater monitoring stations and Remote Operated Vehicles; and (3) to collect a library of baseline data on physiological, biophysical, bio optical and genetic diversity of coral reef ecosystems near DoD installations in three geographic areas.

BENEFITS: This research will provide a set of quantitative baseline data, as well as advanced methods and technology for the assessment of benthic ecosystems near DoD installations. The FRR fluorometry is based on the same biophysical principles, as several other active fluorescence techniques, but it provides significantly greater quantity of parameters. This information is extremely valuable in the identification and quantitative assessment of specific environmental stresses (e.g., elevated temperature, excess irradiance, nutrient limitation, etc.). It is anticipated that the application of SCUBA based FRR technology will help identify and distinguish between natural and anthropogenic stresses to benthic organisms.

ACCOMPLISHMENTS: As part of genetic characterization of DoD coral reef communities, DNA libraries from model coral species have been collected in three geographic provinces. Fifteen new genes of fluorescent proteins from corals have been cloned. Both Caribbean and Indo-Pacific corals were found to contain multiple genes of fluorescent proteins coding for three basic colors: cyan, green and red. The fourth gene type, discovered in the Indo-Pacific Acropora genus but not found in Caribbean corals, codes for non-fluorescent purple-blue coloration. The genetic and bio-optical information from this research is used for the development of optical protocols for assessing the diversity and health of coral reefs at DoD installations. The impact of two main natural stresses (elevated temperature and excess light) on the photosynthetic activity and fluorescent properties of coral has been elucidated. A library of baseline fluorescence and photosynthetic characteristics has been collected for all studied species under a variety of environmental conditions and stresses. The research revealed that the stressed coral can be readily diagnosed by using the FRR fluorescence signatures, even at early stages of stress development.

TRANSITION: Specifications for replication and implementation of the package will allow DoD to reproduce the prototype in order to scale the project up for mapping and monitoring coral reef plots under DoD purview. The core technology will be embedded in the software products developed during this project, so users will have a wide choice of system components, including platform, imaging system, analysis tools, and rapid survey protocol.

PROJECT SUMMARY

PROJECT TITLE & ID: An Integrated Approach to Understand Relationships Between Shallow Water Benthic Community Structure and Ecosystem Function; CS-1335

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Linda Schaffner and Dr. Iris Anderson, Virginia Institute of Marine Science, Gloucester Point, VA

FY 2004 FUNDS: $246.7K

DESCRIPTION: Biocriteria based methods, such as the multimetric Benthic Index of Biotic Integrity (B-IBI), have been applied to elucidate regional and local water and sediment quality impairments and physical habitat disturbance in the Chesapeake Bay. Although this method serves as a good indicator of anthropogenic disturbance, its relationship to key functional attributes of aquatic ecosystems, such as primary production and respiration, nutrient cycling, and food web structure, is not known.

This project will couple the B-IBI approach with more detailed investigations of benthic community structure and function as a means of assessing the relationships among military activities, integrity of benthic communities, and ecosystem function within the shallow waters of the Chesapeake Bay estuarine system. Specific objectives are to: (1) use the B-IBI to assess benthic community health at military installations spanning a range of salinities and stressor types; and (2) identify relationships among B-IBI metrics, food web structure, primary production, respiration, and nitrogen cycling along gradients of impairment in the Chesapeake Bay, at both military and non-military sites.

BENEFITS: This research will improve and expand existing tools that will help scientists and DoD installation managers better understand how to manage and restore estuarine ecosystems. Biocriteria based approaches will play a central role in water quality management in the future.

ACCOMPLISHMENTS: Detailed field investigations of benthic community structure and ecosystem function were conducted at shallow water habitats adjacent to the Langley Air Force Base (LAFB), VA, and at two additional high mesohaline/polyhaline sites located in the southern Chesapeake Bay for comparative purposes. Based upon historical water quality data and field characterizations of potential control sites, Thorntons Creek in the Severn River of the Mobjack Bay, NC was identified as an appropriate control site that is relatively pristine with comparable sediment types, physical characteristics and exposure as LAFB. In order to improve detection of stress in the lower estuary using the B-IBI and ecosystem function measurements, the southern branch of the Elizabeth River was selected as a highly disturbed end-member site for comparison to LAFB and the pristine control site. Week-long field studies were conducted at each of the three sites during 2003. At randomly selected stations within each site, large and small sediment cores were collected and returned to the laboratory for analysis. Water quality parameters were measured concurrently with sediment sampling at each field site.

TRANSITION: To help the military utilize the results of this project, a technical guidance document based on the findings of this study will be produced. This document will consist of an interactive DVD based presentation that will make use of multimedia presentation formats (e.g., text and figure based description of B-IBI methodology with digital video clips demonstrating appropriate sampling methods).

PROJECT SUMMARY

PROJECT TITLE & ID: Predictive Spatial Analysis of Marine Mammal Habitats; CS-1390

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Andrew Read, Duke University, Beaufort, NC

FY 2004 FUNDS: $190.5K

DESCRIPTION: At the present time, there are no analytical tools with which to predict the distribution of marine mammals at spatial and temporal scales of relevance to Navy training exercises. The Navy must be able to conduct such exercises to maintain readiness while avoiding adverse effects to marine mammals. The objectives of this project are to: (1) develop and test the robustness of existing and novel spatio- temporal models of marine mammal distribution, as predicted by physical conditions of the marine environment; (2) design a novel, hierarchical framework for analyzing marine mammal distributions across annual, seasonal and synoptic time frames; and (3) assemble a spatial decision support system that allows Navy users to analyze model outputs and ancillary oceanographic data across multiple forecasting time scales.

Spatially explicit statistical techniques will be used to determine how physical habitat features influence the distribution of marine mammals. A subset of both traditional and novel statistical model approaches will be evaluated to determine which are most robust in understanding marine mammal habitats under different oceanographic conditions and data limitations. The tests will be structured by the spatial and temporal constraints of the observation and environmental data, the taxonomic group of marine mammals evaluated, and the geographic regions assessed. These approaches provide a flexible framework for spatio-temporal data, which is highly appropriate for modeling multi-scale and multi-temporal ecological processes. An analytical toolbox will be developed for the compilation and analysis of relevant habitat/mammal survey data that synthesizes statistical model results into products describing the predicted distribution of cetaceans.

BENEFITS: The Spatial Decision Support System will provide the Navy with state of the art tools to predict the distribution of marine mammals from readily measurable environmental parameters. This will allow the Navy to develop and implement improved mitigation procedures to protect marine mammals without degradation of realistic training exercises.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: Several potential Navy users of the Spatial Decision Support System have already been consulted, including personnel from the Naval Facilities Engineering Command, Atlantic Division and Atlantic Fleet Environmental Support. In the early development stage of the prototype tool, potential users will be contacted for a technology needs and ability assessment that will provide guidance of the specific technologies and software packages to be used in the creation of the toolbox.

PROJECT SUMMARY

PROJECT TITLE & ID: Predictive Modeling of Marine Mammal Density from Existing Survey Data and Model Validation Using Upcoming Surveys; CS-1391

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jay Barlow, NOAA Southwest Fisheries Science Center, La Jolla, CA

FY 2004 FUNDS: $483.3K

DESCRIPTION: The Navy and other users of the marine environment need to be able to estimate the density of marine mammals within their operational areas in order to conduct Environmental Assessments (EA) and to comply with regulations. The objective of this project is to build spatially explicit models that predict cetacean density in the eastern North Pacific based on geographically fixed factors and environmental variables. Another goal is to improve the ability to estimate cetacean abundance in small geographic areas in order to improve EAs and to better guide the location of Navy activities. The last phase of the project will include written software interface to make model results accessible to the Navy and their contractors.

The approach consists of four tasks: (1) further development of analytical tools for spatial modeling from line-transect data; (2) development of spatially explicit models based on the collection of cetacean survey and environmental data from 1986 to 2002; (3) validation of these models using new survey and environmental data to be collected along the U.S. west coast and in the eastern tropical Pacific; and (4) evaluation of the predictive power of these models across seasons using aerial survey data collected in the California Current region in winter/spring. It is anticipated that this research will develop and validate density models for species with more than 100 sightings, approximately 20 species of toothed whales and 4 species of baleen whale. Additional environmental variables will be added that are trophically closer to cetaceans by analysis of existing net-tow samples and acoustic backscatter data.

BENEFITS: The final product of this research will include a software tool to estimate the summer/fall cetacean density for the majority of species within any arbitrary region of the study area if given the measured or predicted field of environmental variables for that region.

ACCOMPLISHMENTS: This is an FY04 New Start.

TRANSITION: The software will be used by the Navy and their contractors who develop EAs of range activities and special research projects. Analytical developments will be published in peer-reviewed literature and will be widely available for use on line-transect data from other parts of the world.

APPENDIX D
Pollution Prevention Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Next Generation Fire Suppression Technology Program; PP-1059

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Gann, National Institute of Standards and Technology, Building and Fire Research Laboratory, Gaithersburg, MD

FY 2004 FUNDS: $1,000K

DESCRIPTION: Halon 1301, the predominant and critical total flooding fire suppressant installed in weapons systems, is no longer in production due to its deleterious effect on stratospheric ozone. The objective of this program is to develop and demonstrate, by 2005, environmentally acceptable and user-safe processes, techniques, and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. This effort leverages prior SERDP-funded research and the Research, Development, Test, and Evaluation (RDT&E) infrastructure created under the ongoing DoD's near-term research program.

The research approach consists of six parallel Technical Thrusts, closely integrated to achieve specific milestones within an 8-year time frame. This approach was developed collaboratively by government, industry, and academic experts in fire science, the contributing technical disciplines, instrumentation, testing, and Halon 1301-protected weapon systems. Following are the six Technical Thrusts which embody 24 separate research elements.

1. Risk Assessment and Selection Methodology develops a process for choosing among alternative technologies by applying modern decision-making concepts.

2. Fire Suppression Principles establish the mechanisms of flame extinguishment using detailed experimental studies and computational models leading to new approaches for fire control.

3. Technology Testing Methodologies select, adapt, and develop test methods and instrumentation to obtain data on the effectiveness and properties of new suppression approaches.

4. New Suppression Concepts define new ideas for fire suppression based on chemical and physical principles.

5. Emerging Technology Advancement accelerates a variety of processes, techniques, and fluids that are currently under development.

6. Suppression Optimization develops the knowledge to obtain the highest efficiency of each candidate technology.

This is a "living" program representing the best current thinking for achievement of the objective, yet adaptable as the knowledge base grows. There are always risks in such an undertaking. For instance, there might be no chemicals that perform well for all the desired properties; no new fire suppression technologies might emerge; optimization principles might not improve mediocre approaches sufficiently; and lab-scale measures might not adequately predict real-scale performance. This research is designed to provide the scientific understanding to maximize the likelihood of overcoming risk factors.

BENEFIT: The outcome of this program will be demonstrated alternatives to Halon 1301. This will enable DoD weapon system managers to remove their dependence on a key ozone-depleting substance while minimizing fiscal and operation barriers to implementation.

ACCOMPLISHMENTS: The Nuclear Magnetic Resonance (NGP) is developing both improved understanding to guide the search for and identification of candidates worthy of further consideration. The following is a list of highlights achieved in FY03:

- The NGP has identified several previously untested compounds for consideration as alternatives to Halon 1301. These include two compounds containing the pseudo-halogen nitrile group, as well as some bromofluoropropene oxides, bromofluoropropenes, and bromofluoroethers. These will be acquired and tested in the coming year.

- The NGP has measured the behavior of suppressant droplets as they encounter a rod-like obstacle in their path to the fire. They tend to accelerate away or rebound from the rod surface, rather than stick to or shatter on it. The concentration of droplets behind the rod is significantly lower than the upstream value, explaining why suppression of obstructed fires is more difficult.

- The NGP has developed the capability to simulate on the computer the observed behavior of a gas phase suppressant with a single clutter object and the perturbing effect of a second object. The aerodynamic drag on the secondary clutter can create high and low pressure regions on the leading and trailing sides of the clutter, leading to either higher or lower suppressant requirements depending on the geometry of the clutter.

- In real-scale fire suppression tests, flare-ups of the fire and pressure surges have been observed as the agent is applied. If experienced during flight, these could have a negative effect on aircraft survivability. NGP research has found that the cause is enhanced combustion of a vaporizing liquid fuel that mixes with air more efficiently in the turbulence accompanying suppressant delivery. The overpressure risk is low unless insufficient amounts of suppressant are applied to a fire. Design equations based on the results of fire suppression tests that fully cover the range of actual fire conditions should obviate the problem.

- NGP research into enhanced powder panels has met with both success and high visibility. Live fire testing confirmed the results of laboratory testing: effective fire suppression with panels that are 30% thinner and lighter and can release four times the powder.

TRANSITION: This is an eight-year, comprehensive research and development (science and technology) effort with leveraged funding from all DoD Services, industry, and academia. Successful sub-projects will be further developed within this program. Successful projects will be transitioned into DoD engineering programs to further develop the technologies for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Replacement of Non-Toxic Sealants for Standard Chromated Sealants; PP-1075

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan J. Fletcher, U.S. Air Force Research Laboratory, Wright Patterson Air Force Base, OH

FY 2004 FUNDS: $220K

DESCRIPTION: The objective of this work is to formulate and test candidate non-chromated sealants that will provide equivalent or improved properties as compared to the existing chromated sealants while meeting the military specifications of MIL-S-81733C. An additional goal is to reduce the volatile organic compound (VOC) content of the materials by 65%.

Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. Under this project team's guidance, a chromate-free corrosion inhibiting sealant was developed, tested, and transitioned to the field. A new polymer was developed that is characterized by properties beneficial to corrosion-inhibiting sealants: (1) rapid cure times without a reduction in work life; (2) pleasant odor; (3) excellent rheological properties; (4) excellent cure at low temperatures; and (5) high solvent resistance. The proposed work is directed toward using this new polymer to formulate corrosion inhibiting sealants for all the types and classes of MIL-S-81733.

BENEFIT: The benefits of this project include: (1) reduced use of hexavalent chromium and VOCs; (2) development of longer shelf-life sealant formulations; (3) development of primerless sealant formulations; and (4) expansion of technology enabling the replacement of other chromated sealants.

ACCOMPLISHMENTS: The team has developed and tested a non-chromated sealant that can be used to seal and provide corrosion protection. This project has developed a family of salts that can replace hexavalent chrome and formulated them into a newly developed class of polymer that has greater storage stability and rapid cure. The new material not only has the advantage of eliminating chrome waste, but of reducing VOCs by 65%, reducing waste disposal by 75% due to improved storage stability and improved application properties. The new sealant is scheduled for release to the market this fall 2004. It will be a direct substitution for the chromated sealants and can be transitioned easily via shop trials, test applications and material substitution. The remainder of the project will focus on material qualification and the development of different Types and Classes of material.

TRANSITION: MIL-S-81733 will be revised and implemented throughout DoD to incorporate the new non-chromated sealant compound while meeting all the other specification requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Critical Factors for the Transition from Chromate to Chromate Free Corrosion Protection; PP-1119

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rudolph Buchheit, Ohio State University, Columbus, OH

FY 2004 FUNDS: $172K

DESCRIPTION: The overall goal is to acquire a fundamental understanding of the chemical and physical processes and mechanisms of corrosion protection by chromate-based coatings applied to metal surfaces with a specific focus on corrosion protection of aluminum alloys. Specific objectives are to: (1) define a set of phenomenological and fundamental rules that describe the role of microstructural heterogeneity in chromate conversion coating formation and breakdown; (2) define the relationship between chromate conversion coating structure and chemistry, and coating properties for coatings applied under non-ideal conditions such as those that exist during coating applications in manufacturing and military maintenance depot environments; (3) determine the extent to which application method, coating age, and alloy substrate chemistry affect the self-healing nature of chromate coatings; and (4) develop rapid, quantitative, and predictive tests to assess properties and performance of chromate conversion coatings.

BENEFIT: Chromate corrosion protection technologies are expensive to operate and generate much hazardous waste. The expected benefit of this research is an increased fundamental understanding of the mechanisms of corrosion protection by chromate-based coatings. Ultimately, this information will support the development of effective chromate-free alternatives.

ACCOMPLISHMENTS: This effort has found that much of the distinctive phenomenology of chromate coating formation and breakdown is associated with inorganic polymerization of hydrated chromium species. From this central idea, consistent explanations for a variety of chromium conversion coating behaviors ranging from coating formation to coating aging, and self-healing are being constructed. Additionally, the notion of inorganic polymerization has been used as the basis for developing a related conversion coating process based on vanadium chemistry. A coating based on vanadate chemistry is being developed and evaluated to determine if this conversion coating meets military specification. This effort is also demonstrating the use of ion-exchange compounds for storage and release of environmentally friendly inhibitors in organic corrosion inhibiting primers and paints.

TRANSITION: All Services and DoD partners are continually appraised of the results from this fundamental research, and this information will be used to aid in modifying procedures and specifications for corrosion protection by coatings.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Conductive Polymers as Environmentally Compliant Coatings for Corrosion Protection; PP-1148

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Zarras, Naval Air Warfare Center, China Lake, CA

FY 2004 FUNDS: $375K

DESCRIPTION: Corrosion prevention using new conductive polymer (CP) coating materials will be the focus of this project. Environmentally compliant formulations combined with a benign process for the application of these coatings will provide the DoD community with an attractive alternative to current chromate-containing coatings. For years the chromate-containing coatings have been used to treat aluminum alloys such as 7075-T6, 7075-T3 and 2024-T3. Many DoD platforms such as the F-18, F-16, F-22, Joint Strike Fighter, MV-22, CV-22, H-60, C-141, C-130, C-5, and P-3 Orion aircraft use these chromium treated alloys. Hexavalent chromium (Cr^{+6}) has been identified as a health threat, and because of its toxicity, is currently highly regulated. New EPA regulations governing air emissions and lower Occupational Safety and Health Administration (OSHA) permissible exposure limits (PEL) have greatly reduce the levels of Cr^{+6} allowed to be discharged into the industrial environment where workers will risk exposure to this known carcinogen. Therefore, chromate-free coatings are needed that also exhibit equal or superior corrosion protection. CP coatings provide such an opportunity to reduce these hazardous materials, eliminate Cr^{+6} from coating formulations, allow compliance with new environmental regulations, and reduce hazardous disposal costs while ensuring mission readiness and worker safety. Several key steps to demonstrate the concept are:

Preparation of CP Powders: The first phase of this study is to prepare kilogram quantities of demonstrated poly(bis-(N-methyl-N-hexylamino)phenylene vinylene) (BAM-PPV) materials at the Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, CA. Concurrent with this effort will be the preparation of 10-gram quantities of oligoaniline acrylate polymer (OAP) by Rensselaer Polytechnic Institute (RPI) at Troy, NY. The NAWCWD-prepared BAM-PPV has been well characterized and has shown conclusive evidence of corrosion inhibition from constant current (galvanostatic) and constant potential (potentiostatic) measurements. These electro-chemical studies were conducted in concentrated salt-water solutions and provided quantitative evidence in reducing the pitting corrosion of aluminum alloys. The procedure for scaling up these CP materials has been successfully demonstrated at the 200-gram scale in moderate yield and high purity. Scale-up to kilogram quantities will proceed using the same procedure. Purity will be demonstrated by the same characterization techniques as previously used for the multi-gram batches (Nuclear Magnetic Resonance [NMR] and Defense Supply Center [DSC]). One small batch of the water-borne polymer, WAM-PPV, has been prepared, hence there is risk in scale-up, however, no difficulties are anticipated. RPI will prepare multi-gram quantities of OAP. Copolymers will be prepared with monomers used in the paint industry such as butyl acrylate, methyl methacrylate, and ethyl hexyl acrylate. This synthetic effort will focus on control of the Mw of polymer to allow easy processability during coating applications.

Paint Formulations with BAM-PPV and Benign Applications of these Materials: CP will be prepared for use in three different chromate-free formulations/processes. Water-borne paint/primer formulations (using water-soluble polymers or water-emulsified polymers) will be coated onto aluminum alloy substrates 7075-T6, 7075-T3, and 2024-T3. BAM-PPV materials will be dissolved/dispersed in liquid CO_2 formulations and coated on the same coupons at NAWCWD. (OAP will not be formulated pending corrosion testing of the neat material.) BAM-PPV materials will be used in powder-coating formulations developed at NAWCWD and coated onto these coupons by the Naval Aviation Depot, (NADEP) Jacksonville, FL using their spray booths. These three processes eliminate all solvent VOC content. Some CP coatings will also have a topcoat, such as MIL-C-27725 (translucent polyurethane topcoat), to compare with current coatings.

BENEFIT: The expected payoff is fourfold: (1) increased environmental safety by reducing toxic metals; (2) increased endurance of military equipment subject to corrosion conditions (humidity, seawater, and salt spray); (3) increased mission readiness; and (4) significant cost savings by reducing painting/depainting waste treatment.

ACCOMPLISHMENTS: The scale-up and purification of the BAM-PPV powder has been completed. The improved synthetic process has yielded over two kilograms of pure BAM-PPV conductive powder. The pure BAM-PPV has been shown to provide equal corrosion protection when compared to a chromate conversion coating (CCC) on Al 2024 alloys for 336 hours in neutral salt fog exposure. The BAM-PPV can now be potentially used as a replacement for CCC. Current testing of the BAM-PPV is ongoing using a variety of electrochemical and spectroscopic measurements to understand the mechanism by which the BAM-PPV can protect aluminum alloys. Additionally BAM-PPV has been incorporated into several military coating systems and is undergoing vigorous testing for FY04.

TRANSITION: This approach is based on a tight feedback loop between industry and end-users to provide a fast-track approach to product development for fleet-wide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Clean Dry-Coating Technology for ID Chrome Replacement; PP-1151

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Bruce Sartwell, U.S. Naval Research Laboratory, Washington, DC

FY 2004 FUNDS: $150K

DESCRIPTION: Chrome plating is heavily used throughout the DoD on almost any system subject to wear - aircraft, ships, tanks, guns, hydraulics, etc. In order to avoid the high volume waste streams inherent in wet plating technologies, the research team proposed a dry-coating method - plasma sprayed Tungsten Carbide-Cobalt (WC-Co) for internal diameter (ID) as small as 1.5 inches. Recent work funded by Defense Advanced Research Project Agency (DARPA), Office of Naval Research (ONR), and the commercial sector has shown that plasma spray with small (1-10um) or nanoscale powders (20um agglomerates or 20nm particles) produces very smooth coatings with the porosity and adhesion of high-velocity oxygen fuel (HVOF). Development of a suitable spray method for miniature ID guns will extend the plasma spray process to 1.5" ID to reach most of the actuator components, and modification of these guns may permit us to reach 1" ID for the smallest pins, hydraulic actuators, and other components. For some applications, such as sidewalls of grooves in IDs, or very thin-walled, heat-sensitive components, the electro-spark deposition (ESD) process is likely to be more cost-effective. ESD is a consumable electrode micro-welding technology with heat input that is extremely small and limited to the surface layer, and it is ideal for small areas and difficult geometries.

The objective of this project is to develop an ID coating technology that is clean, can be used for rebuilds, and is environmentally acceptable. This will be accomplished in three tasks: (1) conducting research on the deposition of smooth, high quality plasma spray WC-Co coatings on IDs greater than 2.5", using existing guns with small particles and with agglomerated nanoparticles, (2) developing and testing new miniature ID plasma spray gun for use with small particles and nano-agglomerates which could drive the minimum coatable ID down to 1", and (3) ensuring that the technologies not only provide good performance at an acceptable cost, but also fit the diverse needs of maintenance operations.

BENEFIT: The immediate environmental benefit of the thermal spray approach is the complete elimination of hexavalent chromium (Cr^{+6}) mist and the chromium-contaminated toxic wastes associated with chrome plating, stripping, and masking operations. This coating method has the potential for significant cost reduction in both production and sustainment. In general, WC-Co coatings at least 2 - 3 times longer than hard chrome. This leads to lower frequency-of-repair, better mission-readiness, and the ability to keep a lower spare parts inventory. The much reduced production time over chrome plating gives faster turn-around in overhaul operations, also enhancing mission readiness and reducing inventory requirements.

ACCOMPLISHMENTS: The WC-based plasma spray coatings are an acceptable alternative to hard chrome for ID applications in diameters of 3" or above. In fact, given the performance of the F300 spray gun, the method appears practical for diameters as small as 1.6". This makes the method viable for both utility actuators and flight surface actuators, but not for small IDs. The wear resistance of the WC-Co plasma spray coatings appears to be superior to electroplated hard chrome, while its abrasion resistance is similar.

TRANSITION: The project is designed to feed directly into an equipment and process development and demonstration/validation program that will be able to follow rapidly upon the completion of the SERDP program. The final deliverable will be a technical report detailing the plasma spray methods that are ready for demonstration and validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduced Particulate Matter Emissions for Military Gas Turbine Engines Using Fuel Additives; PP-1179

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mel Roquemore, Air Force Research Laboratory, Wright-Patterson Air Force Base, OH

FY 2004 FUNDS: $575K

DESCRIPTION: It is estimated that U.S. military aircraft emit about 600,000 kg of particulate matter into the atmosphere each year. Most of this particulate matter is in the form of soot particles with diameters less than 2.5 microns ($PM_{2.5}$). There is a growing body of evidence that these small particles cause both health and environmental problems. The technical objective of the project is to develop one or more fuel additives for JP-8, JP-5, and diesel fuels that will reduce both the mass Emissions Index (EI [M]), (grams of $PM_{2.5}$ emissions/kilogram of fuel) and the number density Emissions Index (EI [ND]), (particle number density/ kilogram of fuel) of $PM_{2.5}$ at the exhaust exit of military gas turbine engines by 70%. The additive should be benign to the environment and the fuel system, cost no more than $0.01 per gallon of fuel, and not reduce engine performance and life. Three complementary technical approaches will be followed: (1) fundamental approach, (2) Quantitative Structure Activity Relationships (QSAR) approach, and (3) select and test approach. The fundamental approach is to conduct basic experiments with additives that have shown a tendency to reduce $PM_{2.5}$ emissions and give insight into the additive mechanisms so that improved additive formulations can be developed. The QSAR approach will provide a mathematical formula that correlates $PM_{2.5}$ reductions to molecular, chemical, and physical properties. The formula will be used to select the next generation of additives to be tested. The select and test approach involves obtaining additives from additive companies and testing them. The companies will be given the results of the additive tests so they can reformulate their additive package and submit it for the next round of testing.

BENEFIT: The insights gained from these studies will be valuable to the understanding of PM formation processes and provide other researchers with a valuable resource for the design of next generation PM mitigating additives. The fundamental experiments involve simple experimental geometries that can be easily modeled. That information will be useful in developing and designing low PM emissions combustors. Finally, an additive or additives will be identified which reduces PM emissions from gas turbine engines by 70%. In the long term, Base Commanders and managers will be able to meet military readiness and local air quality standards of the Clean Air Act Amendments (CAAA) (1990) and upcoming amendments to this Act.

ACCOMPLISHMENTS: The research efforts in the first three project years have provided a fundamental understanding of the effects of oxygenated compounds on soot formation across a range of combustion environments. The fundamental insights into the effects of oxygenated compounds on soot formation and the research methodologies that led to them form the foundation for the research that will be conducted in the final year of the project. The data show that the nitro-alkanes will reduce soot in all the laboratory burners, except for the diffusion flame. This observation is similar to the trend observed with ethanol addition in the opposed flow diffusion flame. Modeling work has begun to explore the understanding of the mechanism more fully using a chemical kinetic mechanism. The preliminary modeling results suggest that the understanding of the mechanism may be incomplete as it does not match the trends observed in the shock tube and the opposed-flow diffusion flame.

TRANSITION: The project will provide a new methodology for evaluating additives to reduce PM emissions from turbine and diesel engines and provide a fundamental understanding of PM emissions from turbine and diesel engines for military and commercial applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Compliant Sprayable Low Observable Coatings that Facilitate Rapid Removal and Repair; PP-1181

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Kovar, Foster-Miller, Inc., Waltham, MA

FY03 COMPLETED PROJECT

DESCRIPTION: Since the enactment of the 1990 Clean Air Act Amendment (CAAA), the U.S. military and aerospace industry has achieved large reductions in emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) from aircraft coating application and removal processes. The National Emissions Standards for Hazardous Air Pollutants (NESHAP) sets limits averaging approximately 400 µg/L of VOCs for general aircraft coatings; however, specialty coatings, including radar absorbing material (RAM) coatings for low observable (LO) aircraft were exempt from the 1998 NESHAP implementation. Although many RAM coatings contain a very high level of VOCs (greater than 600 µg/L), the EPA agreed to exempt LO coatings due to a lack of suitable low VOC RAM substitutes and the comparatively low volume of usage at that time. Over the next decade, the U.S. military plans to deploy several new weapons systems that utilize LO technology and to retrofit several existing systems to render them more "stealthy." As a result, the emission of VOCs from RAM coatings is expected to increase up to two million pounds per year.

This project developed an innovative No-VOC Low Observable Coatings (NVLOC) system that met all current and projected DoD mission requirements for RAM coatings, and effectively eliminated the generation of VOCs and HAPs in the initial application. In addition this coating permits improved, low-cost methods for spot removal and repair of these environmentally compliant LO coatings.

BENEFIT: The immediate environmental benefit will be the elimination of the disproportionate amount of VOCs and HAPs generated by the application of LO coatings. Successful implementation will result in a nearly 100% reduction in VOC emissions generated during the spray application of RAM coatings. Potential cost savings related to the elimination of VOCs is estimated to be between $9 to $30 million annually. These No-VOC coatings may also lead to a rapid, effective HAPs-free coating removal process. Radical reductions in labor hours are expected. More environmentally friendly coating removal processes may also be feasible in the future.

ACCOMPLISHMENTS: The project's UV-curable RAM coating can be applied as a multilayer system while maintaining the excellent performance properties of a single layer system. VOC testing resulted in a measured VOC content of the coating between one and two% by weight. The synthesis was successfully scaled up to liter size quantities. A prototype "hand-held" version of UV system was successfully demonstrated. A vertically integrated team including platform providers, lamp supplier, robotics integration and large scale resin synthesis has been assembled for the successful completion of the current project and for follow on effort to develop the complete system.

TRANSITION: This environmental benign coating technology will provide a tremendous reduction in the life cycle cost as well as improved availability/mission readiness of LO aircraft with potential applications for other weapons systems. This project has successfully transitioned to ESTCP.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrostatic Fuel Atomization for Gas Turbines to Achieve Reductions in Particulate Emissions; PP-1184

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. David Guimond, Naval Surface Warfare Center, Philadelphia, PA

FY 2004 FUNDS: $450K

DESCRIPTION: Reducing particulate matter (PM) emissions in today's gas turbine engines is possible with implementation of electrostatic atomization technology. Benefits of implementing this technology include improved fuel consumption at low power, reduced gaseous emissions, reduced carbon fouling, and quantum reduction in fuel pump parasitic loss and cost. Fuel atomization has a first order effect on the formation of PM in virtually all combustion processes. The objective of this project is to develop and evaluate the capability of electrostatic atomization fuel injection technology to achieve reductions in particulate and gaseous emissions produced during the combustion process in gas turbine engines. The current technology consists of a dual-orifice nozzle with electrostatic injectors. CFD Research, Allison, and the Naval Surface Warfare Center Carderock Division (NSWCCD) will perform a proof-of-concept test with an Allison 501-K gas turbine engine. Charged Injection Corporation will adapt the recently patented electrostatic atomization breakthroughs to the 501-K fuel injector primary nozzle.

BENEFIT: The goal of the project is to demonstrate an 80% reduction in $PM_{2.5}$ with electrostatic fuel atomization technology. The baseline emissions of the engine will be compared with the emissions from the same engine after the electrostatic fuel atomization technology has been installed. In addition to emission reduction, the proposed electrostatic atomization fuel injection technology would provide a payback from improved combustion efficiency at part power operation at which ships typically operate. Navy ship propulsion gas turbine engines operate at 33% of full load power capacity, on average; similarly, ship service gas turbine engines operate at 50% of full load power capacity, on average. During typical part power operation at low to mid-range power levels, combustion efficiency is approximately 93%. With the electrically atomized fuel nozzle system, analysis indicates efficiencies of 98%. Annual savings per ship would be $120,000 (three engines x $40,000). Thus the average savings over the fleet of 50 DDG51 ships would be $6,000,000 per year.

ACCOMPLISHMENTS: Design and specification of the prototype electrostatic atomizer has been completed. Measurements of the limiting charging capacity for the atomizer have been made. Diesel fuel has been successfully charged and atomized up to a flow rate of 250 pounds/hr. Designs that integrate electrostatic atomization technology into a fuel nozzle/injector suitable for use in a gas turbine engine have been developed along with a controller. Prototype electrostatic fuel nozzles have been fabricated and will be tested in the near future to evaluate their performance. Numerical simulations have indicated that electrostatic atomization has the potential to achieve the goal of reducing particulate emissions by 80% from current engine levels.

TRANSITION: At the conclusion of the project, NSWCCD will coordinate the transition of this technology to a demonstration program on a fleet ship service gas turbine generator set.

PROJECT SUMMARY

PROJECT TITLE & ID: A NIST Kinetic Data Base for PAH Reactions and Soot Particle Inception During Combustion; PP-1198

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Mulholland, National Institute of Standards & Technology, Gaithersburg, MD

FY 2004 FUNDS: $209K

DESCRIPTION: Polycyclic aromatic hydrocarbons (PAH) are key molecular precursors to soot formation, but there is little known about their rates of formation and evolution in a flame environment or the dynamics and structure of the transition from a large PAH molecule to an incipient soot particle. The overall objective is to develop a National Institute of Standards and Technology (NIST) chemical kinetic database and an accompanying particle formation model that will describe the transformation of fuel molecules to their desired end products of carbon dioxide and water and the undesired end products of PAH and soot. The specific processes to be considered are fuel breakdown to precursors and subsequent growth to PAH, key gas-phase PAH formation/destruction chemical reactions, and key PAH-to-particle transition steps. The database and model will contain experimental data collected in a shock tube and in a novel well-stirred reactor with flow "chopped" PAH injection. Both atmospheric and high-pressure experiments will be performed. The database will be rigorously evaluated and extended with the recently developed NIST CHEMRATE computer program. The deliverable will consist of chemistry and particle-inception models that can be used in computational fluid dynamic models of diesel and gas turbine engines.

BENEFIT: Manufacturers of military aircraft engines have a strong interest in understanding soot formation in gas turbines. The deliverable will be a publicly available NIST database and soot inception model adaptable for use in computational fluid dynamic (CFD) models of diesel and gas turbine engines.

ACCOMPLISHMENTS: Significant progress has been made on modeling heptane combustion including the production of PAHs. The project has also completed: (1) assembly and ignition of a well-stirred reactor; (2) development of optical diagnostic for well-stirred reactor based on laser induced ion mobility with the electrodes in a parallel configuration; (3) preliminary measurements of large PAHs in the well-stirred reactor; and (4) development of a prototype database for heptane combustion and PAH formation. Other major progress made is in the characterization of the chemical content and size distribution of "early" smoke. Several papers, including a 2002 Combustion Institute paper, have demonstrated the similarity of the inverse diffusion flame soot to that of the early soot of a laminar diffusion flame. The study included the first quantitative measurements of the PAH distribution in the early smoke.

TRANSITION: General Electric has agreed to monitor our progress, provide technical guidance when needed, and ensure that our efforts possess transition potential and remain relevant to the needs of aircraft engine designers.

PROJECT SUMMARY

PROJECT TITLE & ID: Computational Design of Corrosion Resistant Steels for Structural Applications in Aircraft; PP-1224

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gregory Olson, QuesTek Innovations LLC, Evanston, IL

FY 2003 COMPLETED PROJECT

DESCRIPTION: In many structural applications for aerospace ultra-high strength steels are used because they can provide the lightest weight for highly loaded systems. These steels, however, lack adequate corrosion resistance and are commonly cadmium coated. The environmental problems with cadmium are intrinsic to the material itself, creating occupational safety and health (OSH) risks and raising maintenance costs throughout the life of all cadmium-plated parts. Many items that are cadmium plated, such as landing gear, are damage intolerant, and sensitive to hydrogen embrittlement and stress corrosion cracking. This sensitivity makes stress corrosion cracking the primary failure mechanism for landing gear. This often causes significant collateral damage to an aircraft, even though the failure usually takes place while it is parked. The development of an ultra-high strength stainless with corrosion resistance and strength to meet the requirements for landing gear has been the focus of traditional alloy development efforts for many years without success. The traditional empirical approach has been too costly and time consuming to be effective. A new technique, using advanced computational materials modeling and systems engineering methods, known as Materials by Design™, was used to design an innovative new prototype stainless alloy during a SERDP SEED project. This prototype, termed S53, proved to be more compelling than any previously developed stainless for this application, warranting a full SERDP project exploring this alloy.

The overall technical objectives of the project were to: (1) explore appropriate processing standards for alloy production processes, component manufacturing processes, and overhaul and repair processes to provide the information required for manufacture of components of the alloy, and (2) provide adequate test data for mechanical behavior, corrosion resistance, and embrittlement resistance and life-cycle cost to prove the ability of the alloy to replace current, cadmium-coated, aircraft structural steels using standard manufacturing techniques.

BENEFIT: The largest impact will be on the reduction of life-cycle cost and toxic waste in DoD squadrons and maintenance depots. Derivatives of the new steel will also be valuable replacements in actuators and for sustainment of legacy systems, which is the reason that the Aging Landing Gear Life Extension (ALGLE) program is assisting in the activities of this program. In addition, this program will provide a clear demonstration of the Materials by Design methodology itself, which holds the promise of much faster and less expensive development of alloys to meet the needs of higher performance, lower cost of ownership, and environmental cleanliness. Engineers will no longer have to compromise their designs to accommodate materials that are available but can determine the materials they need to meet the challenge before them.

ACCOMPLISHMENTS: Alloy properties have now been demonstrated in production scale ingots up to 17 inches in diameter. Data on tensile, fracture, stress corrosion cracking was produced with the S53 alloy meeting all criteria. All studies of comparisons for 3000 lb (17” ingot) and 300 lb (8” ingot) melt indicate no reason there should be any scale concerns with the S53 alloy. Demonstration and certification of the alloy for use in Air Force landing gear systems has started at Hill Air Force Base (AFB) under an ESTCP program.

TRANSITION: The technical approach of the project is designed to bring the alloy to the point of demonstration/validation testing for landing gear components. Based on its alloy development and chrome plating replacement experience, QuesTek will integrate the mechanistic modeling components used to design the alloy to streamline the process optimization and test program at significant reduced cost. In order to bring

the technology to the demonstration/validation stage, it is necessary to produce a steel production specification and heat treatment specification to define the alloy, a steel properties performance database to support the technical case for the new steel, and detailed cost data to support the business case. The Air Force program manager for landing gear has committed to conduct a dem/val project to develop data required to make an implementation decision for the use of this material on Air Force landing gears.

PROJECT SUMMARY

PROJECT TITLE & ID: Green Medium Caliber Munitions; PP-1237

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Roman Fednya, U.S. Army Armament Research, Development, and Engineering Center, Picatinny Arsenal, NJ

FY 2004 FUNDS: $120K

DESCRIPTION: In an effort to address medium caliber ammunition environmental problems in a systematic manner, SERDP recommended that an umbrella program approach be utilized. In response, the U.S. Army solicited the medium caliber ammunition technical community for membership on the Technical Advisory Committee (TAC) to better focus on the large number of diverse environmental issues. The TAC was formed in February 2001 and held a kickoff meeting on 28 March 2001 at Tank-Automotive & Armaments Command-Army's Research Development & Engineering Center (TACOM-ARDEC), Picatinny Arsenal, NJ. Key agenda topics included SERDP program guidelines and identification of environmental problems by the using services and major contractors. Representatives from academia also presented research activities supporting DoD. A green priority matrix identifying specific contaminants and quantities was addressed. The quantification of specific pollutants in the area of lead and toxic materials led to the development of this priority matrix based on the projected future multi-service medium caliber ammunition production acquisitions. The matrix assigned a high, medium, or low priority for the various contaminants and calibers involved.

BENEFIT: The TAC's highest priority is the elimination or replacement of lead and toxic heavy metals. The TAC also provides specialized expertise that can more effectively prioritize environmental needs and timelines to develop Statements of Need (SONs). The nine focus areas include ignition systems, miniature detonators, miniature fuze electronics, propellants, tracers/incendiaries, detonators, paints, sealants/ adhesives, and metal parts.

ACCOMPLISHMENTS: Coordinated with SERDP PP Technology Thrust Area Working Group (TTAWG) to develop FY05 SON addressing the elimination of perchlorate oxidizers in caliber 50 and 20mm incendiary projectiles and 40mm grenade training ammunition containing flash charges. Awarded contracts to ATK Thiokol and Maxpower, Inc., in June 2003, to support propellant research under PP-1363 and chemical battery research under PP-1360. Convened TAC on 1 Apr 2003 to conduct an IPR of on-going FY02 Pollution Prevention projects.

TRANSITION: The TAC is scheduled to prioritize environmental needs and develop SONs in nine medium caliber ammunition focus areas through FY08.

PROJECT SUMMARY

PROJECT TITLE & ID: Twin Screw Extruder Production of MTTP Decoy Flares - Pollution Prevention through Solvent Elimination; PP-1240

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Carol Campbell, Thiokol Propulsion, Brigham, UT

FY 2003 COMPLETED PROJECT

DESCRIPTION: Magnesium, Teflon, and Viton or Hytemp (MTV or MTH) aircraft decoy flares continue to be important countermeasures to protect military helicopters and fixed-wing aircraft against heat-seeking missiles. Environmental and safety concerns are major drawbacks to the current processing technology for manufacturing these compositions. The current processes are batch processes that require transfers of large quantities of highly flammable solvents from one container to another. The solvents, acetone (VOC) and hexane (HAP), vaporize into the atmosphere where they pose both environmental and safety hazards. Numerous events involving personnel injury and death have occurred. Risks of accidental ignitions are high, but eliminating these risks has been shown to be both difficult and expensive. In addition, open burning of scrap and demilitarization of items also present an environmental pollution problem.

Decoy flares produced by a twin-screw extrusion process do not require the use of HAPs or VOCs during manufacture. A continuous twin-screw extruder (TSE) was used to mix/extrude magnesium, Teflon, and polystyrene or ethylene-vinyl acetate thermoplastic binder (MTTP) into a decoy flare composition. The new material met current MTV or MTH countermeasure product performance specifications. Computer modeling, torque rheometry, and capillary rheometry was used to establish the optimal extrusion formulation and process parameters. Strict process safety measures were taken throughout the entire project to ensure the safe operation of this research and development effort.

BENEFIT: The proposed process will significantly reduce the air pollution, personnel health hazards, potential loss of life through solvent fires, and hazardous wastes associated with MTV or MTH countermeasure production. Cost savings would be realized by eliminating hexane and acetone from the manufacturing process. A preliminary cost analysis shows that 3.4 million dollars could be saved in countermeasure production over the next five years by eliminating these solvents. An additional cost savings would result from the improved process yield using the new technology.

ACCOMPLISHMENTS: The MTTP formulation has been fully characterized for safety properties, burn time and spectral output, and rheological properties. A number of screw configuration, temperature, and screw speed studies were conducted. Subsequent inert simulant runs have met with reasonable success. The product collection system and handling arrangements are in place for the full-up formulation extrusion run. All internal safety reviews have been completed. The live material extrusion is expected to be completed by January 2004. Recycling of uncontaminated pre-blend material through multiple extrusion runs has been demonstrated.

TRANSITION PLAN: The developed decoy flare formulation and process will be transitioned to the demonstration and validation phase based on the fully configured Army, Navy, and Air Force decoy flares. A pilot lot will be manufactured for this effort in accordance with the Army, Navy, and Air Force military specifications. This project focuses on cooperation and open technology transfer between government and industry. Objective of this effort is to develop an environmentally acceptable aircraft decoy flare formulation.

PROJECT SUMMARY

PROJECT TITLE & ID: Low Temperature Powder Coating; PP-1268

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Glen Merfeld, General Electric Corporate Research and Development, Schenectady, NY

FY 2004 FUNDS: $746K

DESCRIPTION: DoD currently spends millions of dollars each year in procuring, using, and disposing of toxic and hazardous materials associated with solvent-bourne coatings for corrosion protection of fixed and mobile systems. The use of powder coatings eliminates more than 95% of the toxic and hazardous materials associated with the application of corrosion protection coatings. This SERDP project will provide a pollution-prevention-based solution to the continuing decline of the environment caused by solvent-based paint manufacturing processes as well as the elimination of chromate based primer systems.

In a 24-month project, a team comprised of DoD (NavAir and U.S. Air Force), DOE (Kansas City Plant), and large and small private industries (GE Corporate Research and Development and Crosslink Powder Coatings, Inc.) will identify and develop mission-critical powder coating resins that will eliminate volatile organic compounds (VOCs), chromates and hazardous waste. Specifically, resins that are low-temperature curable (greater than 230F), durable, corrosion inhibiting, and weather resistant will be developed. The new materials and processes will significantly reduce VOCs and hazardous air pollutants (HAPs) when applied to the temperature-sensitive weapons system components. A full system approach consisting of three tasks will be employed in this program, as follows: (1) formulate novel materials, (2) develop powder coating materials, and (3) develop field repair techniques.

BENEFIT: Development of a new low-cure-temperature powder coating technology will improve the manufacturability, use, and repair of temperature-sensitive, coating-protected weapons, aircraft, and auxiliary equipment. Additionally, the elimination of toxic chemicals, VOCs, and the reduction of hazardous wastes will minimize risks to human health and the environment, while also delivering considerable cost savings by avoiding fines for non-compliance to federal, state, and local mandates. In addition, a typical powder costing resin has the potential to reduce labor and material costs by a factor of 10 or more, while total wastes and VOCs can be reduced by a factor of 100 or more.

ACCOMPLISHMENTS: Two promising non-conventional catalysts were identified and a third catalyst based on proprietary GE technology was shown to offer superior low temperature reaction catalysis. Good progress has been made on critical tasks to develop novel resin technologies and in the preparation of coatings based on these. Additionally, parallel research is underway to develop and characterize full powder coating formulations. This work has demonstrated progress in the closure of performance gaps in three key areas: 120°C cure kinetics, impact resistance, and coating hardness. At the same time, competing deficiencies of note remain in chemical resistance and coating surface quality. Promising technical paths have been designed to address the latter issues. These include the use of novel GE resins that have shown outstanding levels of chemical resistance in lab scale studies. The translation of catalyst and new resin technologies to powder coatings holds promise for significant advancement of low temperature cure technology.

TRANSITION: At the end of this project, one or more powder systems will be ready for demonstration and validation on full-size weapon systems and aircraft support structures by military partners.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Solid Waste Associated with Military Rations and Packaging; PP-1270

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jo Ann Ratto, U.S. Army Natick Soldier Center, Natick, MA

FY 2004 FUNDS: $282K

DESCRIPTION: The nanocomposite packaging effort addresses the environmental need for solid waste reduction for military rations. The current packaging uses high barrier multi-layered materials containing a foil barrier to isolate the contents from oxygen and undesirable moisture. This barrier creates waste that is difficult to recycle or biodegrade. The objective of this project is to research and develop a cost effective, environmentally friendly, nanocomposite packaging material that will reduce the amount of solid waste associated with current and future military rations and packaging. The project will produce a novel nanocomposite packaging material that ultimately will eliminate military solid waste due to its recyclability and biodegradability. One promising class of nanoscale materials being investigated is that made from monmorillonite clays intercalated with organic polymers. Montmorillonites are silicate materials arranged in thin sheet-like layers. The ability to intercalate organic polymers in between the layers of the clay is what imparts the unique properties to the composites. Montmorillonite has been shown to reinforce plastics, increase barrier properties, improve dimensional stability, increase heat distortion temperature, and increase flame retardancy.

BENEFIT: If the nanocomposite packaging substitute is successful there will be a reduction in the plastic waste used for the current meal ready-to-eat (MRE). The current materials will be replaced with recyclable or biodegradable nanocomposites with improved properties and potential to reduce the cost of the military packaging.

ACCOMPLISHMENTS: An intercalated polyethylene terephthlate/montmorillonite layered silicate (PET/MLS) film has been produced through film extrusion processing. Microanalysis X-rays have shown that the dendrite-spacing of the MLS platelets has increased as a result of melt processing, but layered-structures are still present in the samples. The PET/MLS systems with and without the maleic anhydride-coupling agent demonstrate an increased Young's Modulus along with a substantial loss in film toughness and strain. Maleated PET/MLS systems do not show any improvement in mechanical properties over the non-maleated PET/MLS films.

Maleated and non-maleated PET/MLS films show an increased degree of crystallization and crystallization rate over the neat PET films. It is believed that both the maleic anhydride and MLS act as nucleating agents for crystallization to occur upon cooling of the nanocomposites from the melt state. No substantial differences were found between the maleated and non-maleated systems in relation to crystallization properties.

TRANSITION PLAN: Material manufacturers will be consulted and involved in scaling up barrier film manufacturing from laboratory-size to industrial-size equipment. Natick technical teams, procurement agencies and industrial partners will participate in the down selection of materials, based on cost and producibility factors. New performance specifications for the incorporation of these advanced packaging materials into processed rations will be completed.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Cost and High-Impact Environmental Solutions for Military Composite Structures; PP-1271

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Sands, U.S. Army Research Laboratory, Aberdeen Proving Grounds, MD

FY 2004 FUNDS: $640K

DESCRIPTION: Resin systems for liquid molding (LM) applications are being implemented with increasing frequency into designed structures for military composite platforms. The use of low-cost resins for LM, however, has a deleterious side effect. The viscosity reducing agent, typically styrene monomer, is a hazardous volatile organic compound that is freely emitted into the environment during mixing, processing, curing, and fielding of the composite structures. The key objective of this program is to formulate low-cost composite resin systems suitable for LM of composite components, including vinyl ester based composites. The project seeks to reformulate resin compositions used in LM fabrication to decrease volatile organic compound (VOC) concentrations, resulting in reduced emissions throughout the composite life-cycle.

The technology being developed includes three approaches to mitigating VOC emissions by modifying existing baseline vinyl ester resin formulations. First, we seek to minimize emissions by decreasing the overall VOC concentrations in the resin blend. Second, we attempt to bind the VOCs into the matrix by increasing the reactivity at the composite interfaces, both surface and fiber interfaces. This last approach will involve substantial changes in the chemistry of the vinyl ester (VE) resins, which will require investigations into the reactivity relationships between the functional monomers in a multifunctional resin blend. A final push to reduce VOCs may incorporate combinations of the above technology approaches.

BENEFIT: The benefit of this project is to reduce VOC emissions across a broad range of composite applications for military platforms. A key to this program will be keeping costs of new resin formulations at reasonable levels to make the new alternatives competitive with current market resins, such as vinyl ester and polyester-based composites.

ACCOMPLISHMENTS: The project team has continued the development of easily moldable, low VOC resins with good polymer properties. The development of fatty acid monomers as styrene replacements in vinyl ester resins by measuring their cure kinetics, thermo-mechanical properties, and fracture properties has been a key focus, due to the extremely low costs of these agricultural based resins. Project efforts have helped formulate a few candidate fatty acid-based resins for scale-up and polymer-matrix composite production. Additionally, the project has successfully determined how to make blends of low and high molecular weight mono-disperse VE monomers. The current approaches to developing the matrix materials and then evaluating a select group of successful candidates in composite form has allowed for significant formulation to be achieved. A large database of materials properties was established based on the base resins. The research team hopes to demonstrate the effectiveness of these resins through fabrication of composite structures and test panels that are currently being fabricated to validate the technology.

TRANSITION PLAN: The resin formulations can be transitioned using key market players in the composites resin industry. The small resin manufacturers currently interested in supplying these technologies include UCB Radcure and Applied Poleramic, Inc. Our close relationships with these companies allow us to successfully develop materials for direct transition into military platforms.

PROGRAM SUMMARY

PROJECT TITLE & ID: Enhanced Electromagnetic Tagging for Embedded Tracking of Munitions and Ordnance During Future Remediation Efforts; PP-1272

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Keith Shubert, Battelle Memorial Institute, Columbus, OH

FY 2004 FUNDS: $387K

DESCRIPTION: Significant advances in the detection of unexploded ordinances (UXO) must be pursued and implemented to enable the DoD to conduct safe and environmentally-benign training missions. Battelle Memorial Institute has proposed embedding radio frequency (RF) tags on ordnance items to aid in locating UXO in the ground. The tag must be secured to the candidate ordnance item and be capable of surviving the delivery system. The tag must also survive ground impact and terrain penetration, as is the case with nonfunctioning (i.e., unexploded) ordnance items. The buried tag will be required to respond to and then signal the tag interrogation module when the detection system is brought nearby. The overall objective of this project is to: (1) advance current RF tag capability to survive the operating conditions associated with munitions; (2) provide information on the munitions location; and (3) create technology compatible with operational and tactical deployment. The approach for this study is to determine reasonable operating objectives for current RF tag technology or other innovative tagging devises and evaluate tag technology against known constraints or newly established and prioritized operational criteria. Several candidate Tag/Interrogator systems will be systematically explored and tested and a recommendation will be made to the Government at the end of the contract.

BENEFIT: The immediate benefit of the successful execution of this project will be the demonstration of the proof-of-principle of successful detection and location of unexploded ordnance and munition items that have pre-embedded RF tags. The additional required materials and processes will be shown to be comparatively inexpensive. The resulting long-term benefit will significantly decreased costs of range remediation because of the much higher probability of detecting UXO with many fewer false alarms.

ACCOMPLISHMENTS: Identified candidate munitions using criteria including high use rate munitions, high dud rate munitions, munitions of reasonable size, cost, munitions with depths of penetration less than three feet, and munitions used in training. The project performed initial experiments that would help keep later design and testing work in perspective. Initial findings were encouraging for both electromagnetic tags at low frequency (100 kHz) and higher frequency RF tags on near-surface munitions. During 2003, this focus was modified to include concerns about the readability of electromagnetic and RF tags near large metal ordnance items. Discussions with SERDP managers and others resulted in increased concern and focus on the dangers of surface and very-near surface munitions. These concerns resulted in an increased emphasis on the potential for using higher frequency RF tags to help locate surface UXO and the initial findings have been encouraging.

TRANSITION PLAN: From the beginning of the project, every effort will be made to ensure that the results and findings of this effort are evaluated in the constraints of eventual DoD implementation. The project team includes key individuals from Navy, Army, and Air Force with munitions and ordnance management responsibilities. The project will also be focused on the next step in the development process that will be the implementation of a demonstration system that will allow more realistic evaluation by the DoD munitions and ordnance community and the appropriate environmental agencies.

PROGRAM SUMMARY

PROJECT TITLE & ID: Elimination of Chlorine Containing Oxidizers from Pyrotechnic Flare Compositions; PP-1280

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Shortridge, Naval Surface Warfare Center, Crane Division, IN

FY 2004 FUNDS: $401K

DESCRIPTION: This research effort will identify feasible approaches for reformulating a variety of pyrotechnic compositions to reduce or eliminate toxic reactants. Current flare compositions use inorganic perchlorate compounds that react to form highly objectionable hydrogen chloride (HCl) as a combustion product. The objective of this research is to formulate and test improved pyrotechnic compositions, which contain high-energy metallic fuels and alloys and non-chlorine-containing inorganic oxidizers, instead of the currently used chlorine-containing oxidizers. Because the replacement nitrate or oxide oxidizers are less reactive than those that contain chlorine, high-energy fuels will be used to make up for the loss in energy. These high-energy fuels will be using Mechanical Alloying (MA) technology. This novel approach permits the creation of fuel particles which combust to generate metal oxides, ultrafine reactive metal droplets, and the hot combustion gases needed to disperse them. Compositions meeting acceptance criteria will be scaled up to prototype scale, and performance tested under static conditions, as well as under simulated flight conditions.

BENEFIT: The new compositions will produce equal or superior emission intensities in the visible and/or infrared regions, as appropriate to the pyrotechnic application. They will also eliminate or reduce the quantity of HCl generated, reducing the burden of HCl pollutants on the environment.

ACCOMPLISHMENTS: Our most encouraging result to date has involved a candidate red signal flare formulation known as RSF-2. It contains no potassium perchlorate, and also no halogen containing additives, such as Teflon. However, it does continue to use strontium nitrate, but in combination with the less objectionable calcium nitrate oxidizer. It produced a red/orange type flame that compared very favorably in dominant wavelength, color purity, candlepower, and burn time to the existing red colored Mk 66 Mod 0 Marine Smoke and Illumination Signal. Although, we studied three different candidate formulations for a green signal flare, they all appeared to burn too quickly at high intensity and with a very washed out (whitish) green color. We have identified possible reformulation strategies that may improve the color and the burn rate of these green flares so that they more closely resemble the fielded green Mk 117 Marine Smoke and Illumination Signal. The optimized green formulations will then be scaled up to prototype size as well.

TRANSITION PLAN: Potential sponsors for the transition of this project include Naval Air Systems Command (PMA-272), Office of Naval Research, Joint Technical Coordinating Group on Aircraft Survivability/AS, and Army and/or Air Force Mixed Expendables follow-on projects, all of whom are interested in improving spectrally balanced flares. Also, the Naval Sea Systems Command, who is funding a related project to design and test environmentally acceptable colored signal compositions, and ESTCP are potential sponsors.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Acceptable Medium Caliber Ammunition Percussion Primers; PP-1308

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Ellis, U.S. Army Armament Research, Development, and Engineering Center, Picatinny Arsenal, NJ

FY 2004 FUNDS: $92K

DESCRIPTION: Percussion primers are used to ignite the propelling charge in medium caliber cartridges. In order to achieve the required reliability, extremely sensitive primary explosive compositions are selected as the initiating materials. Medium caliber percussion primers typically consist of lead azide, lead syphanate, and NOL130 (Naval Ordinance Lab) as well as barium nitrate and antimony sulfide. Although highly effective, these heavy metal compounds have been identified as hazardous, toxic materials and should be replaced. The objective of this effort is to identify, characterize, evaluate, and test environmentally benign candidate materials as potential replacements for the hazardous lead, antimony, and barium compounds in medium caliber ammunition percussion primers. This effort will enhance a new class of non-toxic energetic materials called Metastable Intermolecular Composites (MIC) originally developed by the Los Alamos National Laboratory (LANL) for this application. LANL and TACOM-ARDEC will analyze and characterize the basic structure of MIC materials to fully understand the material properties and behavior. The program will investigate the controlling reaction propagation mechanism of MIC via laboratory experimentation and analyses at LANL. Simultaneously, efforts will be made to enhance the output and stability of the basic MIC formulation with energetic additives and material coatings to make it suitable for the strenuous medium caliber ammunition environment.

BENEFIT: The development of environmentally friendly primers will reduce or eliminate range contamination, mitigate the long term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at the various medium caliber manufacturing facilities. Economic benefits include reduced ammunition, training and production site cleanup costs.

ACCOMPLISHMENTS: Several promising primer compositions have been formulated and preliminarily tested for performance. The primary means of performance evaluation has been via laboratory ignition evaluations. Two MIC oxidizers (tungsten trioxide and molybdenum trioxide) were combined with varying gas additives and have been evaluated and shown to increase the performance of the primer to satisfy action time requirements. Basic material mixing techniques have been established, however, each new formulation requires subtle changes for optimization. Coatings for the nano aluminum and composition sealants have been evaluated to mitigate the adverse effects of aluminum oxidation. Composition ingredient manufacturing has matured to a state suitable for this development work. A patent application has been submitted for one of the primer formulations with discussions started on subsequent submission(s) of other candidate compositions. A MIC information exchange meeting was convened to share progress, safety, and performance information across the various MIC projects.

TRANSITION PLAN: Upon successful completion of this phase of the project, more extensive fabrication, loading, and testing will be required to qualify the green primers for medium caliber application. If successful, the candidate material(s) will be incorporated into the Technical Data Package by Engineering Change Proposal action for use by the Tri-services.

PROGRAM SUMMARY

PROJECT TITLE & ID: Medium Caliber Lead Free Electric Primer (LFEP) Program; PP-1331

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ron Jones, Naval Air Warfare Center, China Lake, CA

FY 2004 FUNDS: $200K

DESCRIPTION: The Lead Free Electrical Primer (LFEP) program is designed to eliminate the use of heavy metals in the production of electric primers used in military medium caliber ammunition. Beyond the environmental contamination that occurs during the manufacture of the lead styphnate and its use in the production of lead containing primers, lead styphnate is known to produce hazardous by-products when the primer is fired. These hazardous by-products are initially airborne and are capable of polluting the surrounding ground, aquifers, and facilities.

The objective of this program is to develop a reliable and effective electrically initiated medium caliber ammunition primer that does not contain harmful constituents. The follow-on full SERDP Program effort consists of three phases. The first phase will be focused on research into candidate metastable intermolecular compounds (MIC) materials and their properties, as well as the advantages/disadvantages of the two candidate primer design concepts. The first phase of the program will also include a down select between the two alternate primer configurations. The second phase of the program will be focused on the integration and test of these MIC materials in the selected primer configuration. The third and final phase of the effort will be focused on a thorough evaluation of the selected primer design in the intended application and will involve the fabrication and subsequent test firing of all-up rounds of ammunition to determine their ballistic performance (chamber pressure, muzzle velocity, and action time) in a broad range of environmental conditions.

BENEFIT: Major benefits derived through the substitution of MIC materials in medium caliber ammunition primers include: (1) reduced health and environmental risks to factory workers during primer mix manufacture and ammunition production processes; (2) reduced risk to operational users who may be confined in spaces contaminated by residual weapons system gases containing lead; and (3) cost savings from the avoidance of cleanup processes at manufacturing and operational locations.

ACCOMPLISHMENTS: There were significant concerns among the safety authorities at China Lake due to the unknown nature of the materials the project is using. To address that end, the latest material was sent through a process called the "New Materials Committee." This process requires testing of the material for friction, electrostatic, impact and thermal stability. The primers were tested and found to be less sensitive than the current, M52A3B1 primer that they are to replace and the material was accepted for testing. The subsequent tests show action times from 3.2 milli-second (Msec) to 5.04 Msec. This is a significant improvement over previous mixtures and very near the specification value of four Msec for the M52A3B1 primer. This data has led the project to try some other formulations and processing techniques using the same general material to achieve a successful replacement. Work has begun to move the processing in the lab to a technique that will be feasible for large scale production.

TRANSITION PLAN: Following successful development and demonstration of a medium caliber LFEP, the Navy, and the Army, will pursue the follow-on development, qualification, and production of environmentally favorable primers for military ammunition applications. These follow-on efforts could include the implementation of an ESTCP or a development program, depending on the maturity of the LFEP concept at the end of the subject program.

PROGRAM SUMMARY

PROJECT TITLE & ID: Chromium-Free Coating System for DoD Applications; PP-1341

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Wim Van Ooij, University of Cincinnati, Cincinnati, OH

FY 2004 FUNDS: $38K

DESCRIPTION: The current corrosion control strategy in the DoD relies on hexavalent chromium to protect the 2024 and 7075 series aluminum substrates of its legacy aircraft. Hexavalent chromium (Cr^{+6}) is a known human carcinogen that is strictly regulated. New coating technologies are required to preserve existing assets against corrosion losses and to minimize the potential for negative environmental impacts. The proposed effort will develop an integrated organosilane coating system for metal alloy structural components in DoD systems. The coating will be chromate-free and will contain little or no volatile organic compounds (VOCs). The proposed technology is based on recent University of Cincinnati invention termed superprimer. The proposed system, consisting of silane, organic resin and nano-particle filler, is amenable to dipping, spraying, wiping or brushing onto any clean metal surface. No conversion coating, either phosphate or chromate, is required. The key innovation underlying this technology is the hydrophobicity transition exhibited by organosilanes. While the unpolymerized silanes are hydrophilic and water soluble, they become highly hydrophobic on desposition, resulting in extremely low water transmission rates. The coating system will work on all major engineering metals such as carbon steel, galvanized steel, stainless steel, aluminum alloys and magnesium alloys.

BENEFIT: The successful development of the coating system will eliminate or dramatically reduce VOCs, hazardous air pollutants (HAPs), and the generation of hazardous waste streams during coating application and removal processes. The current DoD corrosion control strategy utilizes large amounts of Cr^{+6}, a known human carcinogen, in conversion coats and primers. A chrome-free primer with sufficient performance for use in DoD applications is not currently available. The favorable environmental attributes of the proposed system will significantly improve worker exposure and safety and reduce the life cycle cost of the total coating process.

ACCOMPLISHMENTS: There are no accomplishments due to contracting issues that forced the project to start late in 2003.

TRANSITION PLAN: Throughout the project, DoD end users will be involved to ensure technology transfer to DoD applications.

PROGRAM SUMMARY

PROJECT TITLE & ID: Zeolite Conductive Polymer Coating System for Corrosion Control to Eliminate Hexavalent Chromium from DoD Applications; PP-1342

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yushan Yan, University of California, Riverside, CA

FY 2004 FUNDS: $281K

DESCRIPTION: Corrosion costs associated with corrosion prevention and correction of corrosion-generated failures account for approximately 25% of the armed services' annual maintenance budgets, or more than one billion dollars a year. Current effective corrosion control coating systems for alloys especially aluminum alloys used in DoD applications rely on extensive use of hexavalent chromium (Cr^{+6}) in conversion coatings and/or in primers. Unfortunately, chromium is toxic and carcinogenic. Therefore, regulations regarding its use and disposal have become increasingly stringent. A new chromium-free coating system is required to meet corrosion protection performance requirements in all DoD applications.

The overall objective of the project is to develop a new environmentally friendly zeolite system for corrosion control to eliminate Cr^{+6} in DoD applications without sacrificing performance. Zeolite coating systems will be evaluated as "plug-in" replacements for the surface pretreatment and primer layers that are currently used for paint adhesion and corrosion inhibition in Military coating systems. The project will have four major thrusts: (1) development of zeolite coatings on DoD relevant alloys; (2) demonstrate compatibility of zeolite coatings with current Military water-dispersible, polyurethane topcoats; (3) characterization and standard testing of zeolite/topcoat, bi-layer composite/topcoat, and nanocomposite/topcoat systems with benchmarking obtained from performance of current chromium-coating systems; and (4) technology transition.

BENEFIT: The successful development of the proposed zeolite and zeolite conductive polymer (CP) composite coating system for effective corrosion control will eliminate heavy metals exposure to personnel and to the environment, and reduce hazardous waste disposal costs. The environmentally compliant formulation of novel zeolite and zeolite CP composite coating system will provide the DoD community with an attractive alternative to the current pretreatment and primer layer used in Military coatings system while ensuring mission readiness and worker safety.

ACCOMPLISHMENTS: A single solution composition and deposition procedure were developed that produce high quality coatings on all of the aluminum alloys tested (2000, 5000, 6000, and 7000 series). This development will eliminate the need to adjust the solution composition and deposition procedure to suit an individual alloy, and this means significant cost savings. The project has also successfully scaled up the coating process from 1x3" coupons to 3x6" panels. Work is in progress at the University of Minnesota on the development of alternative coatings and coating deposition process that is alternative to in situ crystallization. The goal is to develop a coating process that is low pressure, low temperature, and has a short deposition time.

TRANSITION PLAN: For this effort, a national team has been assembled to tackle an environmental pollution problem affecting all branches of the services. The current team consists of materials developers and DoD end-users (Naval Air Depot/North Island, San Diego, CA). This effort closely integrates materials researchers and end-users. Thus, this teaming will promote a quick transition from materials synthesis and formulations to material qualification and on to direct use by the DoD community.

PROGRAM SUMMARY

PROJECT TITLE & ID: Electrochemical Oxidation of Alkylnitro Compounds; PP-1345 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Highsmith, ATK Thiokol Propulsion, Brigham Young, UT

FY 2003 COMPLETED PROJECT

DESCRIPTION: Energetic materials containing geminal and vicinal dinitro functionalities all arise from chemical oxidation of nitronate anions. This conversion is traditionally accomplished utilizing oxidizing reagents such as the halogens, hypohalide iron (OX^-), and iron II-III/persulfate, among others. All of these reactions are labor intensive and dirty, producing numerous organic and inorganic byproducts. The use of strong chemical oxidizers is particularly troublesome, producing large amounts of active chemical byproducts. These processes result in a significant amount of time and money spent to separate out, treat, and subsequently dispose of these hazardous/toxic waste streams. The objective of this proposed project was the development of general technology for the synthesis of gem- and vic-dinitroalkanes using clean electrochemical oxidation methodology. This approach eliminated the use of strong chemical oxidizing agents and thus their byproducts. This project resulted in the demonstration of a general method for the clean, electrochemical preparation of nitrocarbons of DoD significance.

BENEFIT: Current chemical oxidative methods for the production of dinitroalkanes yield large amounts of chemical process waste in the form of corrosive inorganic salts. The oxidizing reagents themselves are also costly. The use of electrochemical oxidation for the production of defense-related polynitroalkanes will eliminate large waste streams and produce energetic ingredients in more efficient and environmentally responsible fashion.

ACCOMPLISHMENTS: The voltametric investigations of the electrochemical oxidation of 3-hydroxymethyl-3-nitroazetidine (HMNAz), trinitrotoluene (TNT) and phloroglucinol are completed. The oxidation of HMNAz and TNT appear to be very promising to pursue. It is our objective in the near term to perform bulk electrolysis experiments to isolate a significant quantity of HMNAz and TNT for chemical identification. Electrochemical synthesis of 2,3-dinitro-2,3-dimethylbutane is also being worked. A larger laboratory scale setup has been established to support the planned evaluations.

TRANSITION PLAN: This preliminary demonstration of the electrochemical synthesis of these materials will be evaluated in the context of their ability to be economically, environmentally, and responsibly scaled to production levels. Following the successful demonstration of this technology at the bench (25 gram) scale, the processes will be evaluated for their ability to fit in such a facility. This project should provide the fundamental chemical process information to require a follow-on project to fully scale up the process.

PROGRAM SUMMARY

PROJECT TITLE & ID: Novel Approach for Welding Stainless Steel Using Chromium-Free Consumables; PP-1346 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gerry Frankel, The Ohio State University, Columbus, OH

FY 2003 COMPLETED PROJECT

DESCRIPTION: Stainless steels are selected as materials of construction for their corrosion resistance. When they are fabricated into structures, stainless steel components are often joined by shielded metal arc welding. In order to ensure that the welds exhibit sufficient corrosion resistance, filler metals rich in chromium must be used. Evaporation and oxidation of chromium from molten weld pools results in generation of carcinogenic hexavalent chromium (Cr^6) in the welding fume. It has been well documented that significant quantities of Cr^6 can form when using conventional stainless steel filler metals, resulting in a health hazard for the welder.

The objective of the this project was to demonstrate the viability of a novel approach for welding stainless steel using chromium-free welding consumables. This approach utilized Nickel-Copper welding electrodes that will effectively eliminate chromium from the molten weld pool thereby significantly reducing the potential for Cr^6 generation. This resulted in a weld metal that has equivalent mechanical properties to the base metal and is cathodically protected by the stainless base metal, thereby ensuring adequate corrosion protection.

BENEFIT: Release of carcinogenic chromium fumes by welding operations will be greatly reduced if a suitable chromium-free welding electrode and welding process can be developed.

ACCOMPLISHMENTS: The project has shown that chromium -free alternative can be welded with Monel filler metal to create high quality welds with no cracks. The welds pass bend tests and have hardness that is similar to welds made with current filler metal. This indicates that the strength levels will be comparable. Welded samples survived long term exposure to mildly aggressive environments with no evidence of corrosion. Some corrosion was observed after long term exposure to artificial seawater.

TRANSITION PLAN: Following successful proof-of-concept of a chromium-free welding rod, it will be necessary to pursue follow-on work studying optimization of the welding process and proof that such structures have sufficient metallurgical stability, mechanical properties, and corrosion resistance. Considerable work will also be required in a subsequent phase of this project to complete the process development and prove its suitability for adoption in the field.

PROGRAM SUMMARY

PROJECT TITLE & ID: All-Organic Supercapacitors as Alternatives to Lithium Batteries; PP-1359 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Nickolas Prokopuk, Naval Air Warfare Center-Weapons Division, China Lake, CA

FY 2003 COMPLETED PROJECT

DESCRIPTION: The current standard batteries used for many types of ammunition contain both lithium metal, and thionyl chloride and sulfonyl chloride as the electrolytes. Both of these materials are extremely caustic and pose serious environmental risks to worker safety. The objective of this project was to demonstrate at the laboratory scale a supercapacitor using conductive polymers for the electrodes separated by an environmentally benign electrolyte such as propylene carbonate and tetraethyl ammonium triflate. The first phase of this project synthesized organic polymers with significantly different reduction potentials for applications as the supercapacitor electrodes. The second phase focused on the electrical discharge properties as a function of the polymer/dopant ion combinations. Finally, the third phase focused on assembling a supercapacitor displaying the required voltage and currents within the size constraints.

BENEFIT: This material could hold promise as an alternative to the current lithium metal battery technology. This technology can provide the DoD with an environmentally friendly alternative to the current lithium battery technology. The costs would be significantly less than the current technology without the associated environmental risks.

ACCOMPLISHMENTS: Preparation of the monomer precursors has been completed. The monomer 3-(p-fluorophenyl)thiophene has been synthesized. Polymer supercapacitors were constructed from the poly(3-parafluorophenylthiophene) and poly(3-methylthiophene) on carbon paper electrodes. Poly(3-parafluorophenylthiophene) was n-doped and poly(3-methylthiophene) was p-doped. The discharge properties of each individual polymer were investigated separately. In addition, the discharge properties of the supercapacitors assembled from these materials were studied.

TRANSITION PLAN: Upon successful proof-of-principle, the project would be transitioned into a full SERDP project. Additionally, a Cooperative Research and Development Agreement (CRADA) will be pursued to obtain industrial partners to market this product to the DoD user community.

PROGRAM SUMMARY

PROJECT TITLE & ID: Lambda-MnO_2 Solid Cathode for High Energy Reserve Batteries; PP-1360 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Chua, MaxPower, Inc., Harleysville, PA

FY 2003 COMPLETED PROJECT

DESCRIPTION: Oxyhalide-based primary reserve batteries have been the technology of choice for most of the fuse batteries for strategic and tactical applications. Common to this technology are environmental hazards. Even a slight presence of moisture will cause corrosion and the generation of toxic hydrochloride acid gas. The objective of this project was to develop a low-cost, safe, and environmentally benign high-energy and high-rate reserve battery with equivalent energy density to that of the metallic lithium-oxychloride reserve battery. The project replaced the metallic lithium anode with the high energy, high density material, magnesium (Mg), and replaced the oxychloride depolarizer with the high voltage, high capacity cathode material lambda-manganese dioxide (λ-MnO_2).

Four approaches were employed to develop the new Mg/λ-MnO_2 reserve battery. The first approach developed new electrolyte solutions to eliminate dangerous hydrogen evolution and excessive passivation of the Mg anode. The second approach created a new technology for the synthesis of high energy density λ-MnO_2 cathode material to optimize rate capability and deliverable capacity. The third approach focused on cathode processing technology with emphasis on thin film technology. The fourth approach optimized electrolyte solutions and anode materials that will be used in the fuel cells. At the conclusion of the project, six dry Mg/λ-MnO_2 prototype pouch cells with separate electrolyte bottles were delivered for independent testing and evaluation by the government.

BENEFIT: This technology will provide benefits such as lower toxicity, established recycling method, and economic and environmental acceptability. In addition, λ-MnO_2 can also be extended to applications requiring longer operational time whether in reserve mode or in the active mode. The λ-MnO_2 can be a unique cathode for the Land Warrior (LW) application. Targeted technology transition can be broad-based; as both active and reserve batteries for the military.

ACCOMPLISHMENTS: The λ-MnO_2 cathode technology was studied via two methods of synthesis: an acid wash method and an electrochemical method. Both methods used LiMn2O4 spinel as the starting material. The acid-washed λ-MnO_2 was further milled via a ball-milling equipment to produce nano-scale materials. Processing of the positive electrodes were also carried out via a teflonated process to produce thicker electrode, and through a tape casting method to produce thin electrode. All this work has been completed successfully using a lithium half-cell design.

TRANSITION PLAN: Upon successful proof-of-principle, the project will be transitioned into a full SERDP project.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Benign Impact Initiated Devices Using Energetic Sol-Gel Coated Flash Metal Multilayers; PP-1362

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alexander Gash, Lawrence Livermore National Laboratory, Harleysville, PA

FY 2004 FUNDS: $401K

DESCRIPTION: Current medium caliber (20-60mm) munitions are detonated through the use of impact sensitive (stab) detonators. Stab detonators are mechanically activated by forcing a firing pin through the closure disc of the device and into the stab initiating mix. The stab mix, NOL-130, is a mixture of lead styphnate (basic) 40%, lead azide (dextrinated) 20%, barium nitrate 20%, antimony sulfide 15%, and tetrazene 5%. Alternative impact initiated devices (IIDs) that do not use lead and other environmentally hazardous materials are critically needed. The proposed effort will demonstrate that environmentally acceptable energetic sol-gel coated flash metal multilayer nanocomposites can be used to replace the hazardous and toxic components utilized in current IIDs. The proposed IIDs will be made up of a precision energetic foil of metal multilayers (flash metal), along with a ceramic-based energetic sol-gel coating made up of non-toxic and non-hazardous components, such as ferric oxide and aluminum metals. The multilayer foils can be produced using magnetron, physical vapor sputtering techniques. Both the multilayer and sol-gel technologies are versatile commercially viable processes that allow the tailoring of properties, such as stab sensitivity and energy output. Successful completion of this proposed work will result in IIDs that include innocuous compounds, have sufficient output energy for initiation, meet current military specifications, are small, cost competitive, and perform as well as or better than current devices. Flash metal multilayer and sol-gel are expected to be generic technologies applicable to a wide range of devices, especially in small caliber ammunition and submunitions.

BENEFIT: The development of environmentally benign stab detonators and igniters will result in the removal of hazardous and toxic components associated with their manufacturing, handling, and use. This will lead to improved worker safety during manufacturing as well as reduced exposure of Service personnel during their storage and or use in operations. The implementation of energetic sol-gel coated metallic multilayers as new small IIDs will result in dramatically reduced environmental risks and improved worker and user safety risks without any sacrifice in the performance of the device.

ACCOMPLISHMENTS: One promising candidate material has been identified, shown to have reasonable firing energy, and characterized thermal and physical methods. Attempts to optimize this system to ensure successful initiation of a transfer charge are in progress. Those include detailed thermal structural analyses to attempt to understand the relationship between structure and sensitivity and energy output. In addition, this material has been coated with a more energy dense sol-gel film to examine the effect on performance. Reliable and safe methods were developed to process sheets of energetic nanolaminate into test pieces with desired sizes and geometries. A drop ball apparatus was constructed at Lawrence Livermore National Lab (LLNL) for the rapid evaluation of materials to identify promising candidate materials to be transitioned to the Army.

TRANSITION PLAN: This will be a joint effort between LLNL and the U.S. Army's Research Development and Engineering Center (ARDEC) at the Picatinny arsenal. Following successful completion of the SERDP effort, the Energetics and Warhead Division of ARDEC at Picatinny has committed support for the transition of these materials to Army systems.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Friendly Advanced Gun Propellants; PP-1363

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jeff Akester, ATK Thiokol Propulsion, Brigham City, UT

FY 2003 COMPLETED PROJECT

DESCRIPTION: The main energetic component of military gun propellants is nitrocellulose (NC). Where a more energetic propellant is required, NC may be impregnated with nitroglycerine (NG). In addition to this basic formulation, most military gun propellants also require a coating of deterrent plasticizer for burn rate control, and a surface application of inorganic compounds that serve as ignition aids or to provide flash reduction. Stabilizing additives are also added to prolong propellant shelf life. Diphenylamine (DPA), a suspected carcinogen, acts as a stabilizer in the propellant to prevent the deterioration of the nitrocellulose. Barium nitrate, a heavy metal and also a hazardous material, is used in some medium caliber propellants as an oxidizing agent to make the propellant more readily ignitable.

The primary objective of this proposed work was to identify a suitable replacement for medium caliber ammunition propellants that is more environmentally acceptable, has safer properties, provides an increased level of performance, and maintains a reasonably low cost. This effort used thermoplastic elastomer (TPE)-based propellants as a substitute to current medium caliber ammunition propellants. TPEs were suggested for this work since they do not require oxidizing agents such as barium nitrate nor do they require stabilizing agents such as DPA. TPEs can also be manufactured in advanced geometries, do not have plasticizer migration issues, and are immune to moisture problems. The technology used to produce the new TPE propellants is centered on twin screw extrusion.

BENEFIT: TPE propellants offer advantages over typical NC propellants in that they may be manufactured into advanced geometries, do not have plasticizer migration issues, are immune to moisture problems, and may be warmed and re-extruded into new geometries. TPE propellants may be recycled, minimizing propellant waste. Demilitarization work on TPE propellants has suggested that propellant ingredients are largely recovered.

ACCOMPLISHMENTS: The formulation for the 25 mm round has been determined based on theoretical calculations. The toxicological studies for the 3,3-bis(azidomethyl)oxetane-3-azidomethyl-3-methyloxetane (BAMO-AMMO) have been completed and no environmental problems have been identified. The project is currently tailoring the formulation in preparation for the propellant manufacture in early FY04.

TRANSITION PLAN: Two propellant candidates will be identified through formulation development and initial screening at the research and development (R&D) center located within the Thiokol Propulsion branch of ATK in Utah. All propellant ingredients and manufacturing processes will be examined and modified such that they adhere to the most environmentally friendly approach. Military oversight of the ammunition-testing phase of the program will be administered by personnel from the U.S. Army Research Development and Engineering Center (ARDEC), Picatinny Arsenal, NJ.

PROGRAM SUMMARY

PROJECT TITLE & ID: New Explosive Development for Medium Caliber Stab Detonators; PP-1364

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Hirlinger, U.S. Army Armament Research, Development, and Engineering Center, Picatinny Arsenal, NJ

FY 2003 COMPLETED PROJECT

DESCRIPTION: Current medium caliber high explosive projectiles employ an impact sensitive (stab) detonator. The initiating mixture in these detonators is composed of lead styphnate, lead azide, tetracene, and barium nitrate. All of these compounds contain heavy metals that are either mild toxins or produce toxins upon decomposition. It is estimated that over the next five years, 2500 pounds of these hazardous materials will be employed for detonators, excluding waste materials. The objective of this effort was to evaluate potential replacements for environmentally objectionable energetic materials used in small stab detonators for medium-caliber ammunition. The Naval Surface Warfare Center, Indian Head Division provided technical assistance in the synthesis process of the another replacement compound (2,4-Diazido-6-nitramino-[1,3,5]-triazine), plus perform the assembling and testing of the compounds in the M-59 detonator hardware. Pacific Scientific synthesized both explosive compounds. The effort resulted in a feasibility demonstration of these new explosives in the M-59, a representative medium-caliber stab detonator, used in the M-430, 40mm high-velocity grenade.

BENEFIT: The development of environmentally friendly detonators will reduce or eliminate range contamination, mitigate the long-term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at 20mm-60mm manufacturing facilities. It will also result in reduced exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling during production, test, and operational use of medium caliber detonators.

ACCOMPLISHMENTS: In this project, precursor materials have been acquired and fabrication has been initiated. Two new primary explosive compounds were synthesized in large laboratory quantities and tested for run-up to detonation distance as a direct substitute compound for the critical detonator transfer charge. TACOM-ARDEC was the project lead for this project and provided technical assistance in the synthesis process of the polyazidocyclophosphazene compound 1,1-(N,N'-ethylenedinitramino)-3,3,5,5-tetraazidocyclotripphosphazene (ENTA).

TRANSITION PLAN: A final report will be issued which provides an objective assessment of the viability of using the developed small stab detonators for medium caliber ammunition. Based on the results of this final report, it will be determined whether the project will be given follow-on funding.

PROGRAM SUMMARY

PROJECT TITLE & ID: Synthesis, Evaluation, and Formulation Studies in New Oxidizers as Alternatives to Ammonium Perchlorate in DoD Missile Propulsion Applications; PP-1403

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Dewey, Thiokol Propulsion, Brigham, UT

FY 2004 FUNDS: $240K

DESCRIPTION: Perchlorate is found in groundwater and drinking water throughout the U.S. This contamination is primarily attributed to the use of ammonium perchlorate in the solid fuel for rockets and missiles. The objective of the project is to develop environmentally benign solid rocket propellant formulations that do not rely on the use of ammonium perchlorate (AP) as an oxidizer. This objective supports the goal of reducing future AP contamination in groundwater by reducing the need for production and use of AP as an oxidizer in solid rocket motors. An effective medium in which to exploit new materials appears to be composite propellants using ball powder in combination with plasticizers that do not swell the nitrocellulose. The ball powder system is low cost, and sensitive to bismuth compounds for ballistic modification. These compounds can have the same affect as lead catalysts to affect burn rate and lower exponent, but without the environmental impact.

BENEFIT: Perchlorate contamination is primarily attributed to the production and use of AP in solid fuel for rockets and missiles. It has been estimated that more than 24 million pounds of AP is produced each year. This project is designed to develop benign propellant technologies that have a modifiable burn rate and reduce groundwater contamination.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION PLAN: Upon successful development of replacement propellant formulations, this project will work with Government and industry to transition the propellants into missile systems that currently use AP. The lead organization has made significant investments in recent years in pilot and scale up facilities to fill the gap between laboratory scale synthesis of new materials and their use in full-scale production.

PROGRAM SUMMARY

PROJECT TITLE & ID: Robust, Perchlorate-Free Propellants with Reduced Pollution; PP-1404

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. David A. Ciaramitaro, Naval Air Warfare Center, China Lake, CA

FY 2004 FUNDS: $535K

DESCRIPTION: Ammonium perchlorate (AP) is the primary oxidizer in most class 1.3 DoD solid rocket propellants. An estimated 24 million lbs of AP are manufactured per year. As a result of current and past use of this compound, several sites are now highly contaminated. The ammonium (NH4+) and sodium (NA+) salts of perchlorate are extremely soluble and can easily diffuse into both groundwater and surface water.

The objectives of this project are to: (1) formulate an environmentally benign stable ammonium nitrate (AN)/Hydrazinium nitroformate (HNF) propellant; (2) search for suitable methods to allow modification of the burn rate; (3) demonstrate equal or higher performance than state-of-the art AP based propellants; and (4) validate necessary explosive properties such as friction and impact, ballistic properties, stability, and hazard classification. The proposed work will formulate an AN/HNF propellant with a Poly(3-nitratomethyl-3-methyl oxetane) (polyNIMMO) binder. PolyNIMMO is an energetic binder that is not classified as an explosive material, and is highly compatible with HNF. Research has also shown that polyNIMMO is also a very suitable binder for AN. Formulated propellants will be evaluated for mechanical properties, hazard.

BENEFIT: Constant, low-level consumption of AP can have serious health effects. The alternative AN/HNF propellant combination created in this project will meet or exceed today's AP propellant performance while being completely perchlorate free. The combustion products of this propellant are also environmentally benign.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION PLAN: Because of the large similarity of the AP composite propellants, the proposed AN/HNF propellant formulation can be processed in existing composite propellant plants. Therefore, the transition to AN/HNF propellants can be carried out without significant impact on the existing propellant manufacturing facilities.

PROGRAM SUMMARY

PROJECT TITLE & ID: Elimination of Red Water from TNT Manufacture; PP-1408

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ross Millar, QinetiQ Inc., Kent, United Kingdom

FY 2004 FUNDS: $125K

DESCRIPTION: The DoD requires an environmentally benign synthesis route for the manufacture of military grade trinitrotoluene (TNT) which eliminates the shortcomings of present methods, namely the production of red water (arising from the sulfiting process for removing unsymmetrical trinitrotoluene isomers) and other hazardous and noxious by products such as nitrogen oxides (NOx) and tetranitromethane.

This project will develop a process for the manufacture of military grade TNT which will eliminate the generation of red water by removing the need for bisulfite (‘Sellite’) treatment. This will be achieved by increasing regioselectivity in the nitration of toluene so that the formation of meta substituted nitrotoluenes, especially in the step producing mononitrotoluenes, is suppressed. A principal aim is to reduce the proportion of meta substituted nitrotoluenes to levels below 1.3% (instead of the 4 5% levels in current processes); a subsidiary aim is to reduce the formation of tetranitromethane in the final nitration stage (dinitrotoluenes to TNT) from current levels of around 0.5 lb per 100 lb of TNT produced.

BENEFIT: The primary beneficial outcome of this research will to be to make available a manufacturing route to TNT which will avoid the production of red water, without incurring additional environmental penalties. A subsidiary outcome will be cleaner production of TNT using nitration methodologies which reduce the formation of pollutants such as nitrogen oxide off gases and tetranitromethane. The routes are aimed at being directly applicable to manufacturing scale operation.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION PLAN: This project will output successful synthetic routes to a second phase of the project, which will involve collaboration with SERDP or ESTCP and a North American explosives manufacturer to establish the worth of the respective methodologies, with specific regard to scale up potential. A synthesis scale up capability at technical demonstrator scale will form an integral part of this phase.

PROGRAM SUMMARY

PROJECT TITLE & ID: Electroactive Polymers as Environmentally Benign Coating Replacements for Cadmium Plating on High Strength Steels; PP-1411

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Zarras, Naval Air Warfare Center, China Lake, CA

FY 2004 FUNDS: $145K

DESCRIPTION: Currently, the DoD uses cadmium (Cd) plating on high strength steel components, fasteners, and connectors due to its unique combination of properties. However, Cd is coming under heavy environmental, safety and health pressures worldwide because of its high toxicity. Cd provides corrosion resistance in all weapons system environments, fungus resistance, lubricity, good adhesion and consistent torque tension. As a result, the DoD has found no alternative for Cd plating on high strength steel that meets these requirements.

The objective is to demonstrate, as a one year proof of concept, an environmentally benign alternative to Cd plating on high strength steels using electroactive polymers (EAPs). The three phases of the project are (1) synthesis and characterization novel monomeric and polymeric materials that will provide corrosion protection with good adhesion onto high strength steel substrates; (2) electroless deposition of EAP onto high strength steel substrates (a non line of sight coating method); and (3) testing using a combination of accelerated weathering, electrochemical, spectroscopic, and mechanical tests.

BENEFIT: This work will show that specific EAPs can (1) inhibit corrosion, (2) adhere to steel substrates, (3) coat non-line-of-sight components and parts, (4) not induce hydrogen embrittlement or galling, and (5) produce no heavy waste material.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION PLAN: If successful after a one year demonstration, this program will be transitioned to a full SERDP project for FY05. The knowledge gained will not only be reported in the appropriate journals and conferences, but may support other corrosion inhibition research.

APPENDIX E
UXO Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Methods and Tools for UXO Characterization; UX-1199

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Brent Pulsipher, Pacific Northwest National Laboratory, Richland, WA

FY 2003 COMPLETED PROJECT

DESCRIPTION: The risks associated with Unexploded Ordnance (UXO) in soils at Formerly-Used Defense Sites (FUDS) slated for clean up and transfer to the public are a significant concern. There are two types of risks that must be considered: (1) risk of leaving unidentified UXO that could be discovered after clean up has been completed, and (2) risk of spending scarce resources on characterization with a non- optimal characterization scheme or when there is no real threat present. The latter can result in delays for clean up of truly hazardous sites.

This research program evaluated and developed statistical methods and tools to produce characterization and verification plans and data evaluation schemes that appropriately account for these two types of errors. Significant research on UXO detection system performance has been conducted. Pertinent estimates of probabilities of detection and false positive error rates were extracted from these programs to incorporate reasonable expectations of available data. The performance of acceptable methods relative to user-specified tolerance of the two risks (cost and hazard) were evaluated. Once the methodologies were selected, statistical algorithms that were easy to apply or lent themselves to software implementation were developed. Finally, prototype tools were developed and demonstrated in a carefully controlled range simulation environment.

BENEFIT: The statistical methods developed helped provide a mechanism for designing sampling schemes resulting in an acceptable level of confidence that UXO is or is not present on certain portions of a site. The methods will allow the stakeholders to analyze the tradeoffs between sampling requirements and risk of incorrect decisions. A statistically based sampling approach could avoid significant costs of characterization. Specific payoffs are the availability of methods and tools in the form of technical reports, publications, software, and presentations.

ACCOMPLISHMENTS: During FY 2003, the team completed testing of methods for exact calculations of the probability of traversing and detecting a target area where the anomalies follow a Bivariate Normal density distribution. Through site models generated by individuals at Mitretek, a site description and map was provided for a 155mm and 4.2 mortar firing range. The team generated a set of transects and successfully identified 100% of the target locations. All UXO were bounded within the target area boundaries that were provided. The team completed a second evaluation using a new Mitretek site. The team made different assumptions regarding fragment dispersion patterns and other parameters to evaluate the sensitivity of the methods.

TRANSITION: The statistical methods and prototype tools developed under this project will be applicable to many users at DoD facilities where UXO is a concern. Statistical methodologies will be exercised during extended testing on simulated data. A joint Pacific Northwest National Laboratory (PNNL)/Sandia proposal was accepted for FY03 funding under ESTCP to perform initial demonstrations on existing data from completed and characterized sites, followed by final validation in conjunction with a full scale remediation effort at a UXO-contaminated site. Working with UXO site characterization managers, regulators, and stakeholders to apply the methods will be an excellent opportunity for transitioning the expertise developed. Development of a prototype software tool incorporated into the EPA-sponsored visual sample plan (VSP) software suite will greatly enhance the transition of the methodologies to practice.

PROJECT SUMMARY

PROJECT TITLE & ID: Bayesian Approach to UXO Site Characterization with Incorporation of Geophysical Information; UX-1200

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sean McKenna, Sandia National Laboratories, Albuquerque, NM

FY 2003 COMPLETED PROJECT

DESCRIPTION: The occurrence of unexploded ordnance (UXO) on DoD controlled sites is of critical importance as these sites are prepared for return to the public sector. The current practice of statistical characterization of UXO sites is based on classical statistical approaches derived from assuming the occurrence of UXO is the result of a Bernoulli process. This assumption does not allow for spatial correlation of the UXO density, and it is difficult to incorporate ancillary information provided by geophysical techniques and archival site records in an objective manner. This effort implemented an approach for the characterization of the intensity (density) of UXO across a site that made use of archival site records and geophysical information. A doubly stochastic Poisson process defined the occurrence of UXO. The spatially varying intensity of this Poisson process was estimated with spatial statistical algorithms. The result of this description was that the determination of the precise locations of any individual UXO in the subsurface required sampling at its specific location. However, determination of the variable UXO intensity across a site did not require exhaustive sampling and made use of less precise, or subjective information through a Bayesian updating approach. Bayesian updating produced a map of the site that displayed the probability of exceeding a specified clean-up goal. The approach was validated and compared to current UXO site characterization guidelines on carefully controlled synthetic data sets.

BENEFIT: This project provided a new UXO characterization protocol that will significantly improve currently available techniques used to characterize UXO sites by incorporating prior information through a Bayesian approach, by using geostatistical techniques to update that prior information, and by optimizing the characterization using a data worth approach. This protocol was designed to take advantage of the recent investment in detailed geophysical survey technology. The overall benefit of this project was to provide a more efficient and defensible protocol for the characterization of UXO sites.

ACCOMPLISHMENTS: In FY 2003, the team completed a report describing the results of verification testing of the Sandia UXO site characterization approach on the site models generated by Mitretek. The project team completed two rounds of sampling and estimation on this hypothetical site and were able to identify all UXO present using 14 transects. Estimation results, in the form of coordinates defining a polygon that contains all estimated UXO, were sent to Mitretek. Results of the transect samples were used to estimate the extent of the target boundaries. The team completed the final project deliverable, which was a description of the Sandia approach to site characterization that could serve as a user's guide. Testing of the software approaches and additional verification of the approach developed at Sandia was completed.

TRANSITION: The statistical methods and prototype tools developed under this project are applicable to many users at DoD facilities where UXO is a concern. A joint Pacific Northwest National Laboratory (PNNL)/Sandia proposal was accepted for FY03 funding under ESTCP to perform initial demonstrations on existing data from completed and characterized sites, followed by final validation in conjunction with a full scale remediation effort at a UXO-contaminated site. Working with UXO site characterization managers, regulators, and stakeholders to apply the methods will be an excellent opportunity for transitioning the expertise developed. Development of a prototype software tool incorporated into the EPA-sponsored visual sample plan (VSP) software suite will greatly enhance the transition of the methodologies to practice.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Classification of Buried Metallic Objects; UX-1225

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. H. Frank Morrison, DOE, Lawrence Berkeley Laboratory, Berkeley, CA

FY 2004 FUNDS: $151K

DESCRIPTION: The project is performing basic research to develop a systematic approach for design and fabrication of an optimum active electromagnetic (AEM) system based on the methodology employed in the minerals exploration industry in the search for metallic ore bodies. The intent of the optimum system, bounded by practical and theoretical limitations, is to detect, discriminate and classify unexploded ordnance. The design of the optimum system will be achieved through the integration of: (1) a comprehensive set of simulators for determining the responses of arbitrary conducting, permeable bodies; (2) a simple algorithm that determines the principal moments of a target and computes the band-limited frequency spectrum or the transient decay of the response in the principal axis directions; (3) a technical assessment of the current systems and the proposed optimal system, with particular emphasis on the ambient and geological noise levels; and (4) the design parameters for the construction of an optimal prototype.

BENEFIT: The project intends to develop an active EM system that can extract the measurements for the best possible estimates of the location, size, shape, and metal content of a buried metallic object in the presence of an interfering response from the ground and/or non-unexploded ordnance (UXO) metallic objects. The objective is to design an optimum system which provides the best detection of UXO with the lowest field survey cost.

ACCOMPLISHMENTS: In FY03, the project team modified the numerical simulator code for predicting the response of the entire transmitter-receiver system. The team performed a systematic investigation of the uncertainties in the interpretable equivalent sphere parameters as a function of the system parameters. The effects of pulse repetition rate, pulse duration, center frequency, and bandwidth were explored. Results showed that conductivity/permeability product is poorly determined unless data extends out to an equivalent sphere fundamental time constant. However, for magnetic objects, shorter data lengths can often exclude conductivity/permeability products that would result in equivalent sphere fundamental time constants smaller than the last data time.

The project team has completed design and assembly of a laboratory bench system. The prototype uses a $1m^2$ transmit coil that can be employed in three orthogonal directions and an array of eight receivers. Data has been collected and analyzed to extract target parameters.

TRANSITION: The project intends to transition the EM prototype design to the ESTCP for full scale demonstration and validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites; UX-1281

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Leslie Collins, Duke University, Durham, NC

FY 2004 FUNDS: $350K

DESCRIPTION: Until recently, detection algorithms could not distinguish between buried unexploded ordnance (UXO) and clutter, leading to many false alarms. Over the last several years, modern geophysical techniques have been developed with such approaches yielding reduced false alarms in benign conditions. In particular, for sites where anomalies are well separated and ordnance types limited, it has been shown that the combination of phenomenological models and advanced signal processing can classify UXO and non-UXO items correctly. For highly contaminated regions, however, the signatures of multiple anomalies often overlap, vitiating the utility of many of the newer techniques. To address this problem, a synergistic use of advanced phenomenological-modeling and signal-processing algorithms is being employed.

The proposed research program has two principal objectives: (1) the development of new physics-based signal-processing approaches applicable to scenarios in which responses from multiple UXO and clutter items co-exist in a sensor signal, with the goal of discrimination; and (2) the use of information-theoretic measures to define the types of scenarios for which UXO and clutter density is too high to perform classification reliably, necessitating a direct mechanical excavation of an entire region. The first objective will be met by the parallel development of phenomenological models and statistical signal processing algorithms. The latter topic will address circumscription of those regions, presumably in the vicinity of a former bull's-eye, for which discrimination of individual UXO and clutter is intractable due to the high density of target/clutter overlap and the limited information in available sensor data.

BENEFIT: The algorithms that will be developed will provide the ability to separate the signatures associated with different subsurface objects from a composite signature measured by a sensor. Accurate separation of such signatures will permit remediation of sites that cannot currently be considered using conventional techniques. The output of such algorithms can be transferred to discrimination algorithms that have already proven to improve discrimination of UXO from clutter. The signal processing research will result in performance bounds that allow assessment of sensor performance as a function of site parameters. These bounds will also be useful for circumscription of areas for which predicted discrimination performance falls below acceptable levels.

ACCOMPLISHMENTS: In FY 2003, the project team began modifying the Finite Element Modeling/Multi-Level Fast-Multipole Algorithm (FEM/MLFMA) model to incorporate interaction effects so that the linearity of the response from multiple proximate objects could be studied in detail. The team observed that a single-dipole model provided a good fit for the individual signatures predicted by the FEM model, but a linear combination of the individual signatures did not fit the FEM data that was predicted including the interaction effects. The team quantified the additional variability, that is introduced into the signatures as a result of this nonlinearity, to place bounds on eventual performance. The team used models to generated a more substantial database on which to test the separation algorithms.

The team completed an assessment of the simple prescreener to determine the presence of multiple objects for both the GEM-3 and EM61 systems. The prescreener was found to be more effective for the GEM-3 since more information is present. However, in some cases, it is fairly effective for the EM61.

Additionally, the team validated the utility of independent components analysis (ICA) for signature separation, and investigated its behavior on both simulated and experimental data. The amount of variability

that is added to the separated signatures as a result of the separation process was quantified, and showed that it is negligible.

TRANSITION: The project will pursue teaming relationships and will transition algorithms and model codes to the sensor developers and users in the field as they mature. Organized collaborative relations will provide focus for developments of practical systems. Moreover, these organizations, which are responsible for hardware design and measurement campaigns, will gain insight from phenomenological models to assure that the systems are designed and deployed in the most salutary fashion.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Discrimination in Cases with Overlapping Signatures; UX-1282

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill, U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

FY 2004 FUNDS: $460K

DESCRIPTION: The intent of this project is to perform basic research on the use of electromagnetic induction (EMI) sensors and ground penetrating radar (GPR), together, to develop the means for substantially improving buried unexploded ordnance (UXO) discrimination at highly contaminated sites where different signatures overlap. The assumption is that detection has been accomplished and detailed surveying is to be performed around an indicated location. Instrumentation, measurement techniques, modeling and signal analysis will be further developed to enable ultra-wideband (UWB) sensing in multi-position survey schemes around suspected target clusters.

Specific problems addressed are: (1) the case of two or three UXO-sized objects, (2) the "fragment cloud" consisting of many small clutter items that could have the same amount of metal as a UXO, and (3) the screening problem when a single UXO-sized object is amidst or beneath a distribution of smaller fragments. Both EMI and GPR will be used to address all three cases.

BENEFIT: The results of this project will: (1) support development of subsurface sensing and processing systems that will take advantage of broadband data in both electromagnetic induction sensing and ground penetrating radar; and (2) enhance our ability to discriminate UXO from clutter, particularly in areas of high density contamination. This will result in cheaper, more efficient, and especially more reliable surveying for UXO site cleanup.

ACCOMPLISHMENTS: During FY 2003, advanced Monte Carlo modeling was completed to characterize statistically variable, sparse fragmentation cases, to complement the analytical theory for densely and widely (well-)distributed small clutter. Results show beneficial effects in the screening problem of varying the height of handheld EMI sensors, if the clutter statistics are taken into account in new processing schemes.
GPR and EMI measurements were analyzed for a screening problem in which near surface clutter consisted of small shell casings. For the EMI system, this essentially screened the target from view. However, the GPR was still able to detect and discriminate the target object successfully.

Combined ground penetrating radar and EMI (GEM-3) measurements were analyzed for target configurations with a UXO and a comparably sized piece of ordnance fragment nearby. Results show that when the EMI processing is guided by position information from the GPR, distinctive characteristics of the separate contributing items can be inferred, indicating that one is the UXO and the other is not.

TRANSITION: This project will perform basic research applying electromagnetic physics to provide an improved basis for discrimination of UXO from clutter in highly contaminated sites, that is, where signatures of different objects overlap. The result will be further development of instrumentation measurement techniques, modeling and signal analysis to enable ultra-wideband sensing in multi-position survey schemes around suspected target clusters.

PROJECT SUMMARY

PROJECT TITLE & ID: Physics-Based Modeling and Signal Processing for SAR Detection of Former Bombing Ranges and Burial Pits; UX-1283

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Carin, Duke University, Durham, NC

FY 2004 FUNDS: $224K

DESCRIPTION: There is significant interest in developing sensors that can effectively interrogate large areas for unexploded ordnance (UXO) detection in the presence of realistic rough and/or vegetated terrain. For this problem, detection of each UXO at a significant standoff would be ideal. However, more realistically, a large standoff sensor is required to interrogate thousands of acres quickly, with the goal of circumscribing those areas that are most likely to be contaminated by UXO. In this context, rather than requiring detection of each UXO, the goal is detection of a former bombing range. Similar issues hold with regard to detecting a burial pit. One of the few sensors that affords wide area surveillance, at a significant standoff, is synthetic aperture radar (SAR). While SAR is not in general appropriate for detecting each individual UXO, it can detect shallow buried and surface UXO. The principal challenge is detection of a high percentage of such UXO, at a low false alarm rate, such that one can circumscribe a region for subsequent ground-based detection. The approach studies the utility of SAR for wide area detection of UXO in the presence of naturally occurring clutter. Rigorous electromagnetic models will be employed with state of the art signal processing tools to investigate UXO detection in the presence of various soil types, surface roughness, vegetation and subsurface inhomogeneties.

BENEFIT: The electromagnetic models, having been developed and refined for many years, represent a significant asset that will be brought to bear on any future SAR-based UXO program, significantly furthering the transition from optimal sensor design to subsequent sensor deployment. Utilization of the software developed under this program is very inexpensive, given computer resources. Moreover, use of the insight from the software, in the design of an optimal SAR system and associated processing algorithms, can be very cost effective in assuring that the system is properly designed and deployed. Insights gained computationally are far less expensive and time consuming than those learned empirically.

ACCOMPLISHMENTS: During FY 2003, the team acquired measured SAR data from Sky Research, Inc., for the Former Lowry Bombing and Gunnery Range (FLBGR), and applied the hidden Markov tree (HMT) wavelet-based processing algorithms to this data, demonstrating the ability to distinguish man-made and natural targets. The team performed HMT processing to DARPA-collected data at Camp Navajo, and demonstrated the ability to detect the high-density UXO and to delineate the foliated regions.

The team developed a technique whereby a classifier is designed without requiring a separate training set. An information theoretic construct, based on the Fisher information matrix, was developed to adaptively determine which signatures would be most informative if their labels (UXO vs. clutter) were known. These items are then excavated. The technique was applied successfully to JPG V data and has broad applicability, including to wide-area assessment.

TRANSITION: The algorithms will be tested using available SAR imagery from previous ARL data collections, recent collections from Defense Advanced Research Projects Agency's (DARPA's) Foliage Penetration (FOPEN) system, as well as future measurements from other projects. Based on this modeling, and the associated signal processing, the utility of SAR for wide-area detection of UXO in the presence of naturally occurring clutter will be assessed. It is understood that, even for this limited problem class, SAR will not be appropriate for all environments.

PROJECT SUMMARY

PROJECT TITLE & ID: Standardized UXO Technology Demonstration Sites Program; UX-1300

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. George Robitaille, U.S. Army Environmental Center, Aberdeen Proving Grounds, MD

FY 2003 COMPLETED PROJECT

DESCRIPTION: Advancements in unexploded ordnance (UXO) detection and discrimination technologies are necessary to support the operation, restoration, and transfer of the DoD's ranges. UXO characterization technologies can be affected by the variations in site terrain, geology, vegetative cover and weather conditions that are encountered. The establishment of standardized UXO technology demonstration sites allows users and developers to define the range of applicability of specific UXO technologies, gather data on sensor and system performance, compare results, and document realistic cost and performance information.

In order to satisfy both the research and development community and the technology demonstration community, the standardized sites were made up of three areas: a calibration grid, a blind grid, and an open field. The calibration grid allows demonstrators to test their equipment, build signature library, and determine the effects of site-specific variables on a known target set. In the blind grid, the performance of sensors is determined independent of the effects of navigation, geolocation and site coverage uncertainties. The open field documents the performance of entire systems in operations representative of real world survey conditions.

BENEFIT: This program ensured that critical UXO technology performance parameters such as detection capability, false alarm rate, discrimination capability, target reacquisition, and system efficiency are determined through standard test methodologies, procedures, and facilities. The Standardized UXO Technology Demonstration Site Program provides an invaluable resource to both the research and development (R&D) community and clean up project managers evaluating potential technologies.

ACCOMPLISHMENTS: In FY 2003, a second site at Yuma Proving Ground (YPG) opened for technology testing. The first site at Aberdeen Proving Ground (APG) opened in late 2002. Six vendors have conducted demonstrations at the blind grid at the APG, site including Zonge Engineering, GeoCenters, AETC, Inc., Witten Technologies, Geophex, and Jentek. The YPG site has been used by several demonstrators as well. The scoring protocols for both the blind grid and open field were updated in FY 2003.

TRANSITION: The Standardized UXO Technology Demonstration Site Program provides the UXO technology developer with sites for UXO sensor technology testing and demonstration. Other products resulting from the program include a screening matrix of system performance, a series of standardized site protocols, a standardized target repository, and a variety of technology transfer and marketing materials. The Standardized Test Sites program has been transitioned to the ESTCP program for FY 2004.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Classification Using a Static TEM Antenna Array; UX-1309

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Snyder, Zonge Engineering, Tucson, AZ

FY 2004 FUNDS: $110K

DESCRIPTION: Contemporary unexploded ordnance (UXO)-detection literature suggests that precision broadband electromagnetic induction (EMI) measurements, either in the time domain (TEM) or frequency domain (FDEM), provide useful classification information. However, full classification of a target with EMI requires the illumination of the target with a primary magnetic field in three independent directions in order to excite all the principal modes of the target. Current EMI survey methods rely on movement of the transmitter antenna to different locations to provide target illumination from different directions, and measurements are acquired dynamically at speeds that generally preclude the acquisition of precision transients or broadband spectra. Moreover, target classification based on EMI data acquired from moving platforms is further complicated by even small errors in antenna position. As a result, target classifications based on data from a moving platform do not realize the potential suggested by broadband EMI measurements under static conditions. This project is developing and testing an apparatus based on the concept of acquiring static broadband EMI measurements with an antenna array for classification of UXO.

BENEFIT: This system addresses the need for development of non-intrusive, cost-effective, cued object identification, and detailed site characterization for targets previously identified by systems that provide rapid but imprecise surveys of UXO ranges and/or under conditions of clutter or ambiguous characterization. Static free-air measurements have encouraged many researchers with the prospect that broadband EMI can be used as a basis for target classification, and this system will offer a means of acquiring data having the quality of the static free-air measurements over unknown targets resting in situ. With this system, all of the factors presently identified as degrading the quality of target classifications using data acquired from moving platforms (i.e., antenna and platform motion, unfavorable position and attitude, and low signal-to-noise ratio) will have been significantly reduced or eliminated.

ACCOMPLISHMENTS: In FY 2003, the team completed the construction of the configurable loop together with a single 3-axis receiver loop. The team also completed the construction of a field prototype transmitter multiplexer. The design and prototype construction of the receiver multiplexer (Rx MUX) was completed. The team conducted static tests using the configurable transmitter loop together with manual selector switches. They also characterized 10 standard UXO targets placed at a known position beneath the loop. The data helped the team perfect a methodology for processing data from three different transmitter configurations. Revisions to the processing and interpretive software were completed to handle a series of static TEM measurements, possibly having many different receiver locations and a number of transmitter configurations.

TRANSITION: Zonge Engineering has a nearly 30-year history of designing and manufacturing innovative field instruments for geophysical measurement of electrical and electromagnetic fields. This project will leverage existing technology developed by Zonge Engineering. Zonge Engineering will collaborate with the University of Arizona on the development of knowledge-based classification software to characterize targets. If the project is successful in demonstrating the efficacy of static TEM characterization, the hardware and software will be commercially available through the manufacturing arm of Zonge Engineering. Zonge Field Services will also provide the measurement capability as a commercial service.

PROJECT SUMMARY

PROJECT TITLE & ID: Sensor Orientation Effects on UXO Geophysical Target Discrimination; UX-1310

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Foley, Shaw Environmental, Lowell, MA

FY 2004 FUNDS: $220K

DESCRIPTION: The goal of this project is to develop the required technologies for broad application of existing, emerging, and future unexploded ordnance (UXO) discrimination methods in typical field environments, where sensor data is often acquired under conditions far less ideal than those encountered in typical benign prove-out sites.

Preliminary electromagnetic (EM) modeling methods that allow height and orientation variation have been developed with promising results. However, survey specifications for implementation of these techniques have not been developed, nor has a performance evaluation been conducted to define the relationship between the sensor state and inversion results. This performance evaluation is necessary to answer fundamental questions regarding UXO detection and discrimination capabilities under site conditions that become increasingly more challenging to controlled "Proveout" tests. This research and development effort will focus on two technical areas including (1) the collection of advanced auxiliary sensor orientation and position data, and (2) the development of forward and inverse modeling techniques to exploit auxiliary information. The activities take parallel tracks at the outset of the project. First, the data requirements associated with capture of orientation data are defined through field-testing. Orientation sensors are specified, and a data acquisition system is developed. Second, modifications are made to existing UXO discrimination techniques that model targets as EM dipoles. These modifications exploit the orientation data collected concurrent with EM field survey data. These hardware and software paths come together in the testing phase of the system. Here, EM and orientation data are collected under a range of field conditions to quantify improvements to UXO detection and discrimination capabilities using this approach.

BENEFIT: The technologies developed under this program will have a significant impact on DoD UXO clearance activities by facilitating deployment of new and emerging discrimination methods at live UXO sites. By quantifying the realities of field conditions, making appropriate concurrent measurements with geophysical observations, and adapting analysis procedures to model the effects of site heterogeneity, these technologies will bring sophisticated UXO discrimination methods into wide use. The UXO false alarm rate (often quoted as contributing to 70% of the clearance cost) is the dominant financial factor that can be directly addressed by research and development. As such, technologies leading to routine field application of cost-reducing UXO discrimination methods are essential.

ACCOMPLISHMENTS: In FY 2003, refinements to the integrated system configurations were performed as additional data was collected. The integrated system, using the Leica Robotic Total Station, Geonics EM61-MK2, and the Crossbow AHRS gyroscope, became fully functional.

AETC, Inc. started the development of the data modeling software specifications. Evaluation of the existing orientation data sets was completed. Existing data examples were compiled where geophysical data (EM-61) was collected in conjunction with orientation data, performing spectral analysis of the data, and investigating the performance of EM dipole inversion on synthetic 3D data.

Free-air test platform data was collected at the former Lowry Gunnery Bombing Range. Fiducial data sets using the Geonics EM61-MK2 were collected with the instrument stabilized at various orientations. Data sets were obtained over the Lowry test plot, including multiple passes over the test plot and numerous calibration

lines. Additionally, preliminary data has been gathered where physical constraints to the integrated field systems orientation were introduced to help develop strategies for additional field test data collection.

TRANSITION: The transition plan has two elements: (1) full documentation of technical details through reports, journal publications and technical conference presentations, and (2) transition of developed technology to ESTCP for test and demonstration. Regarding documentation, the project plans to transition all developed technology to the UXO academic and industry community through public-domain report, publications, and presentations. Regarding ESTCP, the team expects that this research will mature to the level of field demonstration, and plans to apply to the ESTCP program in future years to fully test, develop, and transition the technology to wide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Efficient, Realistic, Physics-Based Modeling for Buried UXO Based on Time-Domain Electromagnetic Scattering Signatures; UX-1311

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Weichman, ALPHATECH, Burlington, MA

FY 2004 FUNDS: $200K

DESCRIPTION: The aim of this effort is to deliver a software product suitable for immediate transition to time-domain electromagnetic (TDEM) sensors currently used for unexploded ordnance (UXO) discrimination. The methodology will simultaneously address the requirements of high fidelity physics-based modeling for realistic target shapes and vastly accelerated CPU efficiency for forward modeling and inversion, and subsequent discrimination.

The TDEM method has good detection capability for UXO, but interpreting the scattering signature is difficult due to the complicated nature of interaction between low frequency EM signals and conducting targets and the propagation of the signal in the ground. A broad-based theoretical and numerical effort will be undertaken to vastly enhance the physics-based TDEM modeling capability. A highly efficient "mean field" formalism for high contrast electromagnetic (EM) scattering will be applied. This numerical code, together with the enhancements, will be designed to interface with existing EM aircoil and magnetosensor array tools and to extract basic physical characteristics from sensor observations by efficient solution, ultimately in real-time, of the global optimization problem. The mean field approach is based on the fact that the electrodynamics of any compact conducting body may be represented as a superposition of exponentially decaying eigenmodes. These modes are intrinsic properties of the target that may be precomputed and stored in a data base. The approach uses a Green function formulation of the Maxwell equations, combined with a novel representation of the EM field in terms of a smooth set of vector basis functions. This allows the Maxwell equations to be reduced, via appropriate truncation, to a finite- dimensional matrix eigenvalue problem. The eigenvalues represent the decay rates, and the eigenvectors the mode shapes. By combining this data with extrinsic data, extremely rapid voltage and magnetic field predictions can be made and compared with measurements. The extremely fast forward computation enables the practical use of a genetic algorithm (GA) to discover the best fitting target model. The estimated parameters represent a highly efficient and informative input feature vector to a classifier that selects the best match from the target database or rejects the detection as clutter.

BENEFIT: The economic benefit of this work will be reductions in remediation costs due to reductions in false alarm rates from real-time on-site discrimination. The scientific benefit is a completely new method for rapid EM computations that should eventually find application in other areas such as the mining industry and public infrastructure evaluation.

ACCOMPLISHMENTS: In FY 2003, the project team made theoretical and numerical progress in the UXO discrimination research. The team improved the numerical basis of the mean field theory, and was able to extend the computations to targets with very large and very small aspect ratios. Further, the numerical stability was improved. This was demonstrated with the decay constant plots for the various eigenmodes of the targets as a function of aspect ratio.

The project team integrated the genetic algorithm optimization code with the mean field forward theory code. The team performed various inversion experiments to demonstrate the discrimination capability.

The theoretical derivation of the early time theory was completed for both ferrous and non-ferrous targets. The early time theory agrees with analytical results expected for the case of the sphere. These results provide

a physics-based understanding of decay curves that are typically observed spanning the range from early to late time.

TRANSITION: The final software product will contain all required instrument characteristics (transmitter and receiver loop dimensions; orientation and relative position; transmitter current waveform; receiver time gates; etc.) for a wide variety of TDEM instruments, easily augmentable to new configurations as they become available. The Principal Investigator (PI) has been in contact with instrument manufacturers, with whom he has had associations in the past, who have expressed great interest in using the product to enhance their instrument capabilities.

PROJECT SUMMARY

PROJECT TITLE & ID: Multi-Sensor CSEM Technology for Buried Target Classification; UX-1312

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Everett, Texas A&M University, College Station, TX

FY 2004 FUNDS: $409K

DESCRIPTION: The objective of this project is to develop a prototype, time-domain electromagnetic induction (EMI) multi-receiver sensor along with its supporting interpretation software. The research consists of three major tasks including (1) prototype development, (2) forward modeling and inversion, and (3) integrated system tests. Transmitter (TX) and receiver (RX) components and antennas, the digital signal processor, and the display unit will be analyzed, designed, fabricated, and tested. A fast turn-off TX loop antenna featuring step-recovery diodes and temperature-controlled crystal oscillators will generate a large transient signal that interacts with the conductive ground including any buried targets. The transient response due to eddy currents induced in the subsurface will be sensed by multiple RX coils. The forward modeling and inversion will involve the following components: three-dimensional (3D) finite element analysis for evaluating theoretical transient responses, checking faster semi-analytic solutions and resolving hardware design issues; target feature extraction software for matching observed transient signals to known type-curve parametric representations; and nonlinear parameter estimation using smart homotopy methods to match the extracted response parameters with actual target parameters such as unexploded ordnance (UXO) burial depth, orientation, length, aspect ratio, conductivity, and background soil conductivity. The hardware and software will then be integrated into a final, fieldable sensor configuration with a user interface, and tests will be conducted at Texas A&M Riverside and standardized UXO test sites.

BENEFIT: This research will provide the DoD with an innovative tool for UXO detection and clearance operations, enabling a reduction in remediation costs through increased probability of detection with lowered false alarm rates. The multi-RX transient EMI prototype is envisioned to be a cued sensor designed primarily for detailed interrogation of buried UXO-like targets that have already been detected using wide-area or production ground survey geophysics.

The larger near-surface applied geophysics community will benefit from this research as the instrument and its supporting software package can be used for a wide range of environmental, hydrogeological, shallow resource, and geotechnical applications. Understanding the complexity of the EMI response of natural media demands the development of smart multi-RX geophysical technology.

ACCOMPLISHMENTS: During FY 2003, the EMI system prototypes were developed and demonstrated in a laboratory for detection of UXO. The systems were used to map responses from various UXO targets located at different positions in the laboratory. The systems were able to successfully detect these UXO.

The team conducted a theoretical and experimental study of new multi-receiver loop antenna arrays. The results demonstrated that it is possible to develop a high performance antenna array for EMI systems. This could lead to the development of next-generation multi-sensor EMI systems.

A promising approach to time-domain EMI buried metal target discrimination lies in the deployment of multiple TXs and RXs, together with intelligent software routines. The field studies indicate that the spatial and temporal parts of the UXO signal are separable into a simple product of spatial and temporal functions. Both are nonlinear with respect to the relevant UXO equivalent dipole parameters, such as amplitude, position, orientation, and decay rate. The team has also made progress to date in implementing a homotopy-style nonlinear inversion of multi-RX transient UXO responses.

TRANSITION: Significant interest in the research product is anticipated from defense and environmental agencies as well as private companies and academic scientists. The prototype sensor will be fielded at the test site at Texas A&M University, and standardized UXO test sites. At the conclusion of the project, the developed sensor will be delivered to the sponsor, ready for its deployment at actual UXO-contaminated sites. The team will contact private companies to discuss possible collaborative efforts to commercialize the sensor. The team will interact and share information and technology with the applied geophysics and geotechnical scientific communities. Finally, the researchers will widely disseminate the results of the research through presentations at national meetings and through published articles in leading scientific and engineering journals.

PROJECT SUMMARY

PROJECT TITLE & ID: Quantification of UXO Variability for Target Discrimination; UX-1313

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Jonathan Miller, AETC, Incorporated, Arlington, VA

FY 2004 FUNDS: $98K

DESCRIPTION: The objective of this project is to characterize and quantify inherent variability in the electromagnetic induction (EMI) response of a wide variety of real unexploded ordnance (UXO) objects and to understand the implications of these results for discrimination. Data analysis schemes generally assume signals from a particular target class will be the same, but UXO as found in the field exhibit differences from one example to the next due to damage on impact, deterioration over time, or differences or design and manufacturer. The project will establish statistics describing underlying variability of UXO by collecting data from a large number of items excavated from sites around the country.

Discrimination between UXO and clutter is accomplished by applying decision rules to target-specific parameters derived from site survey data. Within the dipole model framework, these parameters are the EMI response vectors associated with each principal axis of the target (ß values), and the decision rules are regions in parameter space. Measurement and modeling errors, as well as inherent variability among the UXO themselves, cause derived parameters to smear and form a cloud in parameter space. The decision rules must be relaxed to encompass the cloud, thereby degrading discrimination performance. This research will reveal and quantify the degree of ß parameter spreading (distribution) which is attributable to inherent UXO variability.

BENEFIT: Results provided by this program, combined with ancillary ongoing and future research, will provide the user community with the tools and information required to reduce false alarms while maximizing detections. Target variability represents both a fundamental limit on the best possible performance of all EMI-based discrimination schemes, and also an important input for optimizing such schemes.

ACCOMPLISHMENTS: In FY 2003, the team compared data from well-characterized test objects (metal spheres, wire loops, and ferrite cylinders) against published analytic solutions to establish accurate correction factors for the sensors. After applying the corrections, good agreement was found when time-domain (TD) and frequency-domain (FD) data for arbitrary targets are translated back and forth. Computer codes were developed that fit analytic models to both TD and FD data simultaneously. These models allow extrapolation beyond the data to determine asymptotes at zero (DC) frequency, and very high frequency. Additionally, three site visits were completed and 561 UXO targets were processed.

TRANSITION: The product of this project will be a concise, easily transferable statistical database. It is expected that it will be highly leveraged and utilized in current and future UXO-discrimination projects. Results will be directly useful for ongoing discrimination work at AETC, Inc.

PROJECT SUMMARY

PROJECT TITLE & ID: Three-Dimensional Steerable Magnetic Field (3DSMF) Sensor System for Classification of Buried Metal Targets; UX-1314

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Carl Nelson, Johns Hopkins University Applied Physics Laboratory (JHU/APL), Laurel, MD

FY 2004 FUNDS: $367K

DESCRIPTION: The objective of this project is to develop an active electromagnetic induction sensor system to measure the three components of a metal object's magnetic polarizability tensor for object classification.

To accomplish the objective, a sensor with a time-domain, three-dimensional (3D), steerable magnetic field (SMF) antenna will be developed. The 3D antenna will be modeled, designed, and fabricated to excite the metal object with directionally varying magnetic field vectors without the need to move the antenna spatially over the object. The horizontal field antennas will use approximations to a sheet current. The vertical field will be generated via a loop. A magnetic field receiver system will measure the object's time-decay response as a function of the excitation magnetic field vector. The sensor will take measurements in the time range of 2 μs to 20 ms (i.e., a frequency range of 50 Hz to 500 kHz). With this wide bandwidth, the sensor system may be able to cover targets as small as plastic landmines and as large as 1000-pound bombs. An algorithm will be developed to classify the object based on the collected data. Validation experiments will be conducted in laboratory and field trials.

BENEFIT: The portable sensor system will provide improved target response data for enhanced classification of buried metal targets. The improved target classification capability of the 3DSMF sensor system has the potential to reduce the false alarm rate associated with unexploded ordnance (UXO) site cleanups, leading to reductions in the cost of site remediation efforts.

ACCOMPLISHMENTS: During FY 2003, the modeling and simulation of the 3DSMF was completed. The antenna hardware was completed and simple functional tests were performed on the antenna and its support electronics. The data collection and control system hardware were completed and functionally tested. The data collection hardware telemetry system and software were also functionally tested.

Research thus far indicates the project team can define a volume, centered on the antenna, of about 40 cm horizontally and 60 cm in depth where there is a MFA variation of roughly 15º. This magnetic field angle (MFA) variation compares favorably with an MFA variation of about 35º for a dipole antenna used as a HMF generator.

The team leveraged work done for other JHU/APL projects to advance the state-of-art in electromagnetic induction (EMI) data collection via wireless web-based data acquisition. The development of a field programmable gate array (FPGA)-based receiver electronics module has reduce the time it takes to collect data with the 3DSMF sensor system.

TRANSITION: The sensor data will be provided to the research community for alternative algorithm development. Information gathered during the prototype sensor system development will determine the next step in the transition plan. Future steps include: (1) Develop concept of operation; (2) Design or construct improved sensor for transition to Demonstration and Validation testing.

PROJECT SUMMARY

PROJECT TITLE & ID: EMI Sensor Optimized for UXO Discrimination; UX-1315

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Herbert Nelson, Naval Research Laboratory, Washington, DC

FY 2004 FUNDS: $704K

DESCRIPTION: The objective of this project is to develop and produce a prototype ordnance-specific electromagnetic induction (EMI) sensor optimized for unexploded ordnance (UXO) detection, classification, and identification.

Advanced technology demonstrations have shown that UXO discrimination information can be extracted from the signals of commercial EMI sensors, even though their design objectives were other than UXO. However, limitations in parameters such as coverage rate, depth of use, and size of UXO that can be examined impose limitations in the available information.

There are three key design issues that will be considered in the initial and subsequent designs of the prototype sensor. These are the trade-offs of frequency-domain (FD) vs. time-domain (TD) systems (or a hybrid approach if warranted), the details of coil design and deployment strategy to yield optimum classification performance (especially for the case of closely spaced targets), and the reduction of system noise. The optimum sensor for UXO discrimination will be specified, and a practicable system that can be transitioned to the commercial sector will be designed, produced, and tested. The existing Multi-Sensor Towed Array Detection System (MTADS) will be used as a testbed for studying deployment issues arising in the course of the research and development activities.

BENEFIT: The benefit of the sensor development will be primarily economic. Costs of a typical UXO remediation are driven by investigation of non-UXO metallic objects. An optimally designed sensor promises both an improvement in detection capability and reduction in the number of non-UXO targets, which will result in a large reduction in the cost of remediation projects.

ACCOMPLISHMENTS: During FY 2003, a collection of test cylinders were characterized in the laboratory using a prototype FD electromagnetic (EM) system. Finite element modeling was performed to verify the experimental results and validate the modeling procedure. Agreement was observed between the experimental results and the model. An apparatus was constructed to make parallel measurements in the time-domain on this same collection of objects. Individual component tests were completed and apparatus validation was initiated.

TRANSITION: In the final year of the program, regular meetings are scheduled with engineers from the major manufacturers of geophysical instruments to keep them up-to-date on development progress. At the conclusion of the program, the team intends to seek funding for a demonstration/validation of the sensor or, if appropriate, transition results to one of these commercial firms.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Evaluation of an Airborne SQUID-Based Magnetic Gradiometer Tensor System for Detection, Characterization, and Mapping of Unexploded Ordnance; UX-1316

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. T. Jeffrey Gamey, Oak Ridge National Laboratory, Oak Ridge, TN

FY 2004 FUNDS: $250K

DESCRIPTION: This project will explore the viability of deploying a Superconducting Quantum Interference Device (SQUID) sensor array in an airborne platform. Current airborne magnetometry systems using Cs-vapor sensors are severely constrained to very low altitude by inherent sensitivity. The SQUID could allow stand off to increase from less than 1 m to 5-10 m, and multiple axis vector measurements will provide unique information for set discrimination and localization. The research approach will focus on developing and demonstrating the capability of high temperature superconducting (HTS) SQUID multi-axis magnetometers and gradiometers for standoff detection of surface and buried unexploded ordnance (UXO). To meet these objectives, the following issues will be systematically addressed: (1) HTS SQUID sensor performance in the presence of the large fields and field changes generated by a helicopter; (2) Compensation of magnetic noise generated by movement of the cryogenic vessel; (3) Active real-time compensation of HTS SQUID sensors based on linear movement through the Earth's field; (4) Development and construction of an extremely stable boom for mounting the SQUID on a helicopter platform; (5) Integration of HTS SQUID electronics packages with current Oak Ridge National Laboratory (ORNL) airborne magnetometer positioning, navigation, and recording systems; and (6) Determination and quantification of detection footprint from a single HTS SQUID array.

BENEFIT: The SQUID array is expected to provide a level of sensitivity and detection previously unavailable in airborne systems, thus enabling the detection and mapping of smaller ordnance items than possible with current cesium vapor magnetometer arrays. This system is expected to enable detection and mapping of large items from greater standoff distances than are possible with current airborne platforms. Vector anomaly attributes of large items have the potential to improve classification.

ACCOMPLISHMENTS: In FY 2003, project decisions were made regarding the development of the fluxgate noise cancellation system. Repairs to the SQUID sensor elements were completed and the new instrument was tested. The two element SQUID was used to conduct the original unshielded operation test in order to verify that the replacement was justified. Results showed that the instrument functioned adequately in a high noise environment, and that the distribution of magnetic noise was comparable to that measured in previous total field tests. Extensive electronics design work was conducted resulting in a configuration that maximized the potential for a successful test, while making use of numerous current assets. Initial vibration tests were also successfully conducted during this year. Although the analysis is not complete, initial visual observation and reports from the pilot indicate that the heavier weight is perfectly acceptable, and that a weight of 15-25 lbs produced the least total vibration.

TRANSITION: The transition approach is based on providing for the implementation of demonstrated and validated SQUID-based sensor technology upon completion of appropriate limited field-testing. The techniques in this project and associated hardware and software that are developed will require additional testing in a full scale field application. Subsequent funding from ESTCP would be pursued to perform the required demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Broadband Electromagnetic Detection and Discrimination of Underwater UXO; UX-1321

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. I.J. Won, Geophex, Inc., Raleigh, NC

FY 2004 FUNDS: $319K

DESCRIPTION: The objective of this project is to advance the current state-of-the-art in broadband electromagnetic sensor technology for underwater detection and discrimination of unexploded ordnance (UXO). A major project goal is to extend the sensor detection range so as to widen the sensor footprint.

Broadband discrimination methods applicable to underwater UXO will be developed based on the EM induction spectroscopy (EMIS) technology pioneered by Geophex. A promising phenomenon, called the current-channeling effect, will be investigated to extend the underwater detection range and extensive field experiments will be conducted to verify such effects. Required sensor parameters and a configuration to maximize the detection range will be determined. Signal processing algorithms accommodating both the eddy current response and the current channeling response will be developed for underwater UXO detection and discrimination. Sensor deployment schemes based on available platforms will also be recommended.

BENEFIT: Clearing underwater UXO poses a variety of technical challenges, including detection, discrimination, survey platform, navigation, and logistics. This research in underwater EMI detection and discrimination will have a major impact in the development of detection strategies for underwater UXO by providing a new sensor technology not only for remediating underwater UXO sites but also for many other applications in marine geotechnical engineering.

ACCOMPLISHMENTS: The focus of the efforts in FY 2003 was to continue the model development and perform some controlled underwater measurements with a variety of metal targets using a 40 cm GEM-3 modified to operate underwater. The team also worked to compare the underwater response to in-air measurements and analyze the results using their modeling algorithms. The team completed theoretical analysis of underwater EMI physics in terms of eddy current response (ECR) and current channeling response (CCR) using a conductive sphere as a model.

The project team completed the first underwater controlled experiment in a sound near Beaufort, North Carolina and confirmed theoretical predictions. The first phase of underwater UXO survey at Mare Island in San Francisco Bay was completed. The team completed an area of about 120 acres, which produced high quality data.

TRANSITION: All codes will be made available through SERDP to interested parties. Geophex will also commercialize the codes along with the instruments it sells.

PROJECT SUMMARY

PROJECT TITLE & ID: Technology Needs for Underwater UXO Search and Discrimination; UX-1322

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jim McDonald, AETC, Incorporated, Cary, NC

FY 2003 COMPLETED PROJECT

DESCRIPTION: The primary objective of this project was to develop a detailed design for the deployment of extended arrays of magnetometer and electromagnetic induction (EMI) sensors for characterization of underwater unexploded ordnance (UXO) sites. Both the sensor and the dynamic control of their depth and orientation at a fixed distance above the bottom were analyzed with a goal of permitting surveys in 0 to 15 feet of water at a vessel speed of several knots. Secondarily, new EMI sensor designs were developed that had the required sensitivity at a standoff distance of 1 to 2 meters to detect even small UXO targets while maintaining the time resolution needed to extract object shape information that can be used for target classification. Finally, high-frequency sonar imaging technology was considered for use in bottom mapping, depth profiling (in real-time), and providing shape information for targets proud (or partially proud) of the bottom.

Many system components developed for the Airborne Multi-Sensor Towed Array Detector System (MTADS) magnetometry array can be directly adapted for a Marine platform. These include the data acquisition and pilot guidance systems, the magnetometer sensors, the navigation control and attitude sensors, the data analysis algorithms, software Graphical User Interface (GUI), and the output graphics, interfaces, and remediation support documentation. In this project, a study was completed to define the support vessel (i.e., deployment concept) and develop engineering design plans for the vessel-sensor platform interface and the two sensor array platforms. Additionally, an EMI modeling study developed the engineering design plans for the new marine EMI array and defined the high frequency sonar system required to support the marine UXO survey system.

BENEFIT: This project produced the engineering design information necessary to develop and deploy a fully functional, marine UXO search system appropriate for the shallow water environment.

ACCOMPLISHMENTS: During FY 2003, the Final Report was delivered, which documented static and dynamic modeling studies of 2, 4, and 10 meter sensor platforms. An in-house EMI sensor modeling study predicting performance in water with varying salinity was completed. A Final Report from Geonics was delivered describing modeling studies of time-domain (TD) EMI systems of various sizes and designs and evaluating the effect of time gates, sediment composition, and signal distortions resulting from various design parameters. Additionally, parametric studies were completed using a 4-meter transmit coil with varying receive coil designs and different types of UXO challenges. A preliminary EMI sensor array design was developed.

TRANSITION: The project is transitioning to an ESTCP effort in FY 2004. Following ESTCP demonstration, AETC, who is not a direct provider of UXO services, will seek as a transition partner an A&E firm specializing in UXO services to commercialize the system and put it into service.

PROJECT SUMMARY

PROJECT TITLE & ID: Ordnance/Clutter Discrimination by Electromagnetic Induction; UX-1323

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Steven Norton, Geophex, Inc., Raleigh, NC

FY 2003 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop signal processing algorithms that employed broadband electromagnetic induction (EMI) data for the purpose of discriminating between unexploded ordnance (UXO) and clutter.

Algorithms were developed and tested for processing both multi-frequency and multi-positional EMI data for UXO/clutter discrimination. Two discrimination approaches were investigated, including: (1) EMI spectroscopy in which the spectral signature of an unknown object was compared to a library of known UXO spectra, and (2) derivation of geometric features characteristic of UXO from multi-positional EMI data. Axial symmetry and a large aspect ratio were identified as UXO-like, whereas an object with a small aspect ratio or irregular shape could be identified as clutter-like. These algorithms were evaluated on a variety of buried UXO and clutter items in standardized test ranges with the goal of determining how discrimination accuracy (probability of correct classification and false alarm rate) was affected by geologic noise and other uncertainties in the data such as sensor position errors.

BENEFIT: The product of this research was computer software for processing both multi-frequency and multi-positional EMI data to identify objects as UXO or clutter with an estimated level of confidence. The software was designed to process either UXO survey data acquired over an area containing many items or data acquired from one item at a time (i.e., in real time immediately upon detection). A reliable method of discrimination eliminates the need for removal of harmless items, thereby significantly reducing excavation costs. This new technology has applications in other areas as well; a notable case is the problem of discriminating between landmines and clutter.

ACCOMPLISHMENTS: In FY 2003, two discrimination algorithms were developed. Both techniques combine multi-frequency and multi-positional data. The team developed and tested a method of deriving generic features of UXO, such as axial symmetry and aspect ratio. The team showed that the method is tolerant of uncertainties in the location of the sensor relative to the target as well as to errors in the estimated target depth. The results showed distinct characterization between flat or irregular shaped clutter objects versus UXO. The EM induction spectroscopy (EMIS) identification algorithm, which utilizes the multi-frequency data, incorporated a floating inphase feature that reduces sensitivity to magnetic geology. Reduction in fitting errors resulting from sensor height variation over targets buried in magnetic soil were observed.

TRANSITION: At the completion of this work, Geophex provided SERDP with all discrimination software and documentation. The software can be marketed with, or independently of, the Geophex GEM-3 multi-frequency sensor.

PROJECT SUMMARY

PROJECT TITLE & ID: An Improved High Power Transmitter for Surveys Using Time-Domain Electromagnetics; UX-1324

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Snyder, Zonge Engineering, Tucson, AZ

FY 2003 COMPLETED PROJECT

DESCRIPTION: Performance of current time-domain electromagnetic (EM) systems is often limited by the signal to noise ratio. One way to increase signal-to-noise ratio (SNR) is to increase the power of the transmitters. The objective of this project was to design and test a proof-of-concept transmitter that provides a transmitter current moment 5 to 10 times greater than that of existing Time-Domain Electromagnetic (TEM) systems used in unexploded ordnance (UXO) surveys. In addition, the step wave form employed in conventional systems was replaced by an impulse wave form.

The transmitter design was based on resonant circuit principles that allowed the transmitter circuit components to perform as if they were connected to a tuned circuit operating at its resonant frequency, thus transmitting power to a resistive load. With a resistive load, the transmitter power was substantially increased as compared to a reactive load presented by the more common untuned transmitter loop. Pulses of current were generated by suspending the state of the circuit with solid-state switches. The circuit generated a current pulse in the shape of a half-cycle of a sine wave. A half-sine waveform resembled an impulse function. In contrast, a conventional TEM transmitter generated a waveform that approximates a step in the current. The spectral content of an impulse was constant whereas the spectral content of a step function decreased with increasing frequency. The change in signal shape alone improved the SNR even if the transmitted power was increased. Critical circuits were designed to attach to an existing transmitter for the purposes of proof-of-concept and to carry out a demonstration/test at a standard UXO test site.

BENEFIT: The SNR is usually enhanced in existing systems by stacking or filtering. Either of these techniques requires low survey speeds. Generally speaking, there is a practical limit that establishes the slowest possible surveying speed. It follows, therefore, that there is a practical limit to the best obtainable SNR. The benefit of this technology will be to obtain better SNRs than is attainable with conventional TEM transmitters and to acquire the data at faster surveying speeds. The higher SNR will provide better detection, lower false-alarm rates, and an increased depth of investigation.

ACCOMPLISHMENTS: During FY 2003, the team completed the breadboard fabrication and testing of 3 variations of the switching circuits required for a transmitter based on resonance principles. Based on the tests, the team predicted they can produce a low-power battery-operated resonance transmitter able to transmit 500-750 A into a small loop.

TRANSITION: The project report will provide the basics needed by any manufacturer to design and implement the technology in their own design. If this development is successful, Zonge Engineering will invest in development of a marketable product following completion of this project work.

PROJECT SUMMARY

PROJECT TITLE & ID: High Resolution Inductive Sensor Arrays for UXO Detection, Identification, and Clutter Suppression; UX-1326

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Neil Goldfine, JENTEK Sensors Inc., Waltham, MA

FY 2003 COMPLETED PROJECT

DESCRIPTION: The goal of this project was to investigate inductive arrays for high resolution unexploded ordnance (UXO) imaging and discrimination. Existing meandering winding magnetometer (MWM)-Array sensor and instrumentation technologies were used to provide estimates for performance against UXO as a function of depth and ordnance properties. The technical approach was to: (1) adapt JENTEK's parallel architecture impedance measurement instrumentation and high resolution imaging sensor array for use with large scale MWM-Arrays for UXO detection and image generation; (2) establish MWM-Array object size and depth measurement capabilities for simple objects and UXO in the laboratory; (3) complete an initial field test of the prototype MWM-Array with adapted instrumentation at an approved test site; and (4) develop criteria for enhancements and provide recommendations for follow-on efforts. JENTEK's MWM-Array technology is based on designs for electromagnetic induction sensor arrays that use a single drive winding with multiple sense elements. The drive creates a shaped magnetic field pattern, which provides a continuous variation in the orientation of the magnetic field relative to the buried ordnance. Arrays of small inductive coils placed throughout the shaped field sense the field variations from conducting or magnetic UXO and clutter. Images obtained from scans over buried objects provide a basis for spatial filtering and signal processing for discrimination.

BENEFIT: This project established the current capability of the original prototype MWM-Array for UXO detection and discrimination. Based on initial results, the Program Office opted to pursue alternative methods for discrimination.

ACCOMPLISHMENTS: In FY 2003, a series of laboratory tests were performed with a high-resolution sensing array to establish a baseline response for the system. This included measurement scans over numerous UXO and pipes at different orientations to demonstrate the imaging capability of the system. The laboratory results were consistent with observations from the field data. The team adapted an existing drive winding and an array of sense elements to work with parallel architecture impedance instrumentation. The team demonstrated that improving (e.g., doubling) the array resolution can be accomplished without affecting the signal-to-noise ratio. Rapid-scanning capability reflecting object orientation and shape and the presence of multiple proximate objects were demonstrated. The team also demonstrated a preliminary size and depth estimation capability using a model-based approach. Finally, the team demonstrated similarity of object signature responses in the laboratory and the field.

TRANSITION: The Final Report includes the results of the adaptation of the prototype for use with a high resolution sensing array, preliminary object model development for use in clutter suppression algorithms, results from both laboratory and field testing, and recommendations for system enhancements.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced Magnetic System for UXO Detection and Discrimination; UX-1327

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yacine Dalichaouch, Quantum Magnetics, San Diego, CA

FY 2004 FUNDS: $878K

DESCRIPTION: This project will develop a hybrid passive and active man-portable Magnetic Tensor Gradiometer (MTG) capable of operating with unprecedented versatility and performance in production ground surveys. The new system will be based on magnetoresistive chips and will provide broadband [direct current (DC) to greater than 100 kHz] characterization of subsurface targets. When the broadband information is processed with advanced algorithms, it will enable the detection and discrimination of unexploded ordnance (UXO) with very high detection and low false alarm rates.

The man-portable sensor will be capable of collecting multi-component magnetic and electromagnetic (EM) data simultaneously in rocky, hilly, and vegetated terrain. The DC magnetic signature will be used to localize the target, using a traditional fit to a static magnetic dipole, and derive a multi-dimensional map of targets on the fly, using a matched filter algorithm. The magnetic-dipole fit will yield the target location, as well as the strength and orientation of the associated dipole moment. Successful implementation of the tensor gradiometer measurement will allow calculation of target parameters from sparser data sets and greater standoff distances than current instruments. Once the target depth is fixed, the wideband EM (frequency-dependent) response for different incident field profiles will be collected to characterize buried UXO, and a frequency-dependent model will be used to extract the magnetic susceptibility, electrical conductivity, shape, and orientation parameters. Discrimination algorithms based on target attributes determined from their magnetic and EM signatures will be used to distinguish UXO from clutter and fragments, and to resolve multiple, offset targets.

BENEFIT: By virtue of its dual alternating current capability, the new system will allow collection of magnetic and EM data in just a single sweep, thereby reducing scanning time by 50%. This will significantly improve efficiency and reduce labor hours and associated survey costs. In addition, this new technology will maximize the survey efficiency by allowing random search paths rather than requiring constant-pitch raster scans. Certain site areas can be identified rapidly as devoid of targets without detailed and time-consuming surveys. Major benefits of this new system, however, may be a significant improvement in the ability to discriminate UXO from clutter and fragments and to resolve multiple targets.

ACCOMPLISHMENTS: During FY 2003, the brassboard Frequency-Domain (FD) and Time-Domain (TD) systems were evolved into multi-axis systems. Work on these systems continued with bench-tests and improvement cycles. A second set of canonical UXO targets were measured and the results were analyzed. Additionally, the team completed initial testing of a complete single sensor FD system. A new data set was collected for several UXO items and a number of well defined clutter items. Tentative thresholds were explored to differentiate and identify UXO targets.

TRANSITION: This project will culminate in a prototype instrument and data interpretation software. The techniques developed in this project and associated hardware and software will require additional testing in a full field application. Subsequent funding from ESTCP would be pursued to perform the required demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: On-Time 3D Time-Domain EMI and Tensor Magnetic Gradiometry for UXO Detection and Discrimination; UX-1328

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Wright, U.S. Geological Survey, Denver, CO

FY 2004 FUNDS: $554K

DESCRIPTION: This project aims to improve the state of the art in detection, imaging, and discrimination of unexploded ordnance (UXO) by evaluation, modification, and testing of existing magnetic and electromagnetic induction (EMI) prototype systems originally designed for other geophysical applications that are closely related to DoD needs for UXO. The objective of this project is to demonstrate that a combination of modified instrumentation and new interpretation algorithms for EMI and magnetometer data, considered separately and together, can result in high probability of detection with reduced probability of false alarms.

This project evaluated three prototype geophysical instruments. The Very Early Time Electromagnetic (VETEM) system is a time-domain EMI system that records both while the transmitter is transmitting and during very early times following transmitter turn-off. It records the magnetic field, rather than the more common time derivative of the magnetic field, with an expected benefit of better target-to-background response ratios. It is expected that the combination of multiple-component early- and late-time data will enhance target discrimination through analysis of differential vector eigencurrent decay rates. The High Frequency Sounder (HFS) is a frequency-domain (FD) EMI system with great flexibility in frequency range. The Tensor Magnetic Gradiometer System (TMGS) is a magnetic system that uses ring-core 3-axis, flux-gate sensors so that not only the gradients of the total magnetic field are recorded, but also the gradients of the magnetic field vector components.

BENEFIT: Typically, in excess of 70% of removal action project costs are for the removal of non-UXO items using current technology. The achievement of the objective of high probability of detection with decreased probability of false alarms by means of enhanced EMI and magnetic sensors and new appropriate modeling and interpretation algorithms can save the DoD billions of dollars.

ACCOMPLISHMENTS: During FY 2003, modifications were made to each prototype system including new antennas for the VETEM system and new antennas and electronics for the HFS. New fluxgate sensors were integrated into the TMGS system and new LabView data acquisition software was written for VETEM and the HFS. The data acquisition software for the TMGS was modified to permit operation while in motion. Laboratory tests of all three systems were carried out to assess their sensitivity and verify the modifications. New methods of data processing were developed for each instrument. Data was collected at the Yuma Standardized Test Site and results were evaluated. Results indicate detection sensitivity of each prototype system performed at a level similar to some of the best existing commercial systems. Data from all systems were used, along with theoretical modeling, to determine the parameters for a new on-time, time-domain (TD) electromagnetic induction system (ALLTEM) and the parameters for a revised tensor magnetic gradiometer system.

TRANSITION: This project will culminate in prototype advanced systems optimized for UXO targets. The techniques developed in this project and associated hardware and software will require validation in a full field application. Subsequent funding from ESTCP would be pursued to perform the required demonstration/ validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Modeling for Sensor Evaluation in Underwater UXO Test Beds; UX-1329

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Raymond Lim, Naval Coastal Systems Station, Panama City, FL

FY 2004 FUNDS: $226K

DESCRIPTION: This project will adapt the sonar performance prediction capability developed at the Coastal Systems Station (CSS) for mine-countermeasure purposes to support design testing and evaluation of sonar systems to locate and identify unexploded ordnance (UXO) in shallow waters. A primary focus of this work will be to build and validate a prediction capability for buried and partially buried targets with high fidelity over a broad frequency range.

Among the sensor technologies being developed for shallow water UXO remediation, acoustics (sonar) is likely to be one of the most important, since it is less range-limited than more traditional magnetic sensor technologies in seawater. CSS has developed the Shallow Water Acoustic Toolset (SWAT), a set of acoustics computer routines that have been used to aid performance evaluation of mine-countermeasure sonar in littoral environments. Central to extending SWAT to accommodate the environmental conditions and sonar concepts envisioned for UXO remediation is the accurate modeling of scatter by UXO shapes in buried configurations. The approach will involve an application of the Kirchhoff approximation with generalized theory of diffraction corrections for target edges at high frequencies (>10kHz). At low frequencies (<10kHz), scattering algorithms applicable to elongated axisymmetric targets based on the transition matrix will be adapted.

BENEFIT: This work will provide the DoD the capability to simulate sonar performance, permitting informed decisions on the relative merits of competing systems prior to their fielding. Sonar designers will be able to optimize design requirements (e.g., frequency, aperture, etc.), optimize operational requirements (e.g., scan rate, tow speed, etc.), and predict operational limits under various conditions.

ACCOMPLISHMENTS: During FY 2003, a method was derived to speed up transition (T)-matrix scattering calculations for bottom targets based on an application of the complex image method to the integrals that arise in target/seabed scattering problems.

An ongoing modeling and measurement effort investigating shallow grazing angle acoustic detection of targets buried in sand was continued with model comparisons against new data for a sphere buried under sinusoidal ripple with different ripple wavelength, ripple heights, and sphere burial depths.

Four UXO shapes spanning a typical range of sizes were acquired for UXO laboratory and field tests. High frequency models of these targets were built into SWAT using the Kirchhoff approximation and generalized theory of diffraction corrections for edges.

TRANSITION: The SWAT tool in its current configuration is freely provided to sonar researchers and designers. The sonar performance prediction capability that is developed under this project will be as well. Following completion of this effort, sonar designers will be able to optimize design requirements (e.g., frequency, aperture, etc.), optimize operational requirements (e.g., scan rate, tow speed, etc.), and predict operational limits under various conditions.

PROJECT SUMMARY

PROJECT TITLE & ID: GEM-3D Sensor Development; UX-1353 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill, U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory, Hanover, NH

FY 2003 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to construct, debug, and demonstrate, at the bench and "backyard" level, a new sensor configuration that would add to the existing GEM-3 frequency domain electromagnetic induction sensor the ability to measure secondary fields in 3-dimensions. When the sensor head of the GEM-3 is horizontal, it is capable of measuring vertical secondary magnetic fields. The existing GEM-3 was modified to record horizontal secondary field components as well, using the concentric coil arrangement for the horizontal coils (two transmitters, one receiver), with the centers of the vertical coils residing over the common mid-point of the horizontal coils. The instrument possesses the same advantages in spatial resolution as the existing GEM-3. New model-based signal processing was developed and applied to data from the device, to infer the shape of metallic targets relevant to subsurface unexploded ordnance (UXO) sensing. This was done in the following limited cases, which were sufficient to demonstrate the potential of the instrumental innovations: some canonical shapes (homogeneous sphere, elongated object, plate-like object), a few complex objects in the near field, and several cases with two or three objects.

BENEFIT: Improved discrimination of subsurface UXO from widespread metallic clutter was at the heart of the research needs for improvement of UXO cleanup assessment and execution. At many real (as opposed to test) sites, false alarm rates are enormous, and as much as 75% of the cost of remediation may go to excavating innocuous items. Recent experience in both the field and lab, using both measurement and rigorous simulation, has highlighted the potential discrimination benefits of using ultra-wideband (UWB) sensors and analyzing the spatial dependence of their signals, in a variety of orientations.

ACCOMPLISHMENTS: During FY 2003, a prototype of the new GEM-3D sensor head was successfully constructed and software modifications were made so that it received all three vector components of the scattered field. The software modifications allowed testing of the new head, and only five frequencies could be received in each channel. Results showed that proper calibration and balance is eminently possible. After the basic system was constructed and reasonable data obtained in all three receiver channels, work proceeded successfully to redesign and implement the DSP so that 10 frequencies per channel could be received.

TRANSITION: The Principal Investigator (PI) is an integral member of the U.S. Army Corps of Engineers (USACE)/Engineer Research and Development Center (ERDC)/Environmental Quality Technology (EQT) team, working on development and demonstration of a new generation of UXO sensing capability. The results will be directly linked into the EQT-funded efforts. Results will also be published in conference and journal forums. Geophex Ltd, the maker of the GEM-3 system, will be directly involved so that any successful advances in the state of the art will be moved immediately and directly into private sector implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Use of Shape Representation and Similarity in Classification of UXO in Magnetometry Data; UX-1354 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jim McDonald, AETC, Incorporated, Cary, NC

FY 2003 COMPLETED PROJECT

DESCRIPTION: In this project, the researchers proposed to go beyond the use of physics-based fitting parameters to make decisions about ordnance classification. The team used target images created from high-density mapped sensor data and pattern recognition techniques (using shape representation and similarity) to extract and exploit image features to provide an additional input for a classification decision. Shape information is a primary component of the visual decision-making process used by the human analyst in the current Multi-Sensor Towed Array Detector System (MTADS) interactive data analysis approach.

The team used new machine-learning algorithms and techniques that were promising candidates for automatically capturing visual clues for sorting unexploded ordnance (UXO) from ordnance scrap. Several inductive leaning algorithms were shown to be successful in interpreting imagery data in other applications. Differences in the algorithms determined the concepts the algorithms induced and the types of data. Multiple algorithms were explored to determine those best suited to separating UXO from scrap using data as it is available in the real world.

BENEFIT: The approach has the promise of producing a pre-screener, which will improve the target analysis process by making it more time efficient and automated.

ACCOMPLISHMENTS: This FY 2003 New Start project received funding very late in the fiscal year. During FY 2003, potential shape algorithms were evaluated using previously collected magnetometer data from an MTDAS survey on the Badlands Bombing Range. Initially data from the seed target area were analyzed. The study was extended to a full 110 acre area on which a vehicular MTADS survey was conducted.

TRANSITION: The transition is expected to be direct. If successful this work could be incorporated into the highly successful MTADS survey platform.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Target Detection and Discrimination with EM Differential Illumination; UX-1355 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Foley, Shaw Environmental, Lowell, MA

FY 2003 COMPLETED PROJECT

DESCRIPTION: Geophysical target signatures recorded from electromagnetic induction (EMI) sensors, such as the Geonics EM-61, may contain extreme levels of background noise in magnetically permeable soils found in some geological conditions. The spatial variation of the soil effects is not separate and distinct from the signatures of buried unexploded ordnance (UXO) at a single frequency or time gate. This minimizes the effectiveness of spatial filtering for separating UXO signatures from soil effects. Existing fixed-geometry, transmitter (TX)/receiver (RX) coincident EMI systems have not produced data sufficient to reliably detect UXO in the presence of strong geologic effects.

The goal of this project was to develop methods and technologies to isolate target signatures from geologic effects in geophysically hostile environments using diversity in transmit/receive geometry and time gates. To achieve these project objectives: (1) a working model for effective differential illumination based on review of theoretical aspects of electromagnetic response to soils was defined, (2) a series of parametrically constrained EMI data sets were collected to explore the range of responses, and (3) data was subsequently analyzed to establish the utility of the concept.

BENEFIT: The project will improve UXO target discrimination in environments where local geologic effects have a strong influence on geophysical signatures. Several recent and planned UXO clearance projects have involved such challenging geological conditions. This improved performance will lead to reductions in the false alarm rate and produce cost savings related to UXO clearance activities.

ACCOMPLISHMENTS: This FY 2003 New Start project received funding very late in the fiscal year. Investigation will continue into FY 2004.

TRANSITION: Upon demonstration of enhanced capability utilizing the algorithms, the work will be transitioned to contractors who collect the data to perform further processing.

PROJECT SUMMARY

PROJECT TITLE & ID: Reducing False Alarms: The Physics of Scrap Discrimination for Magnetic Data; UX-1356 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Leiblich, SIV Technologies, Inc., Worcester, MA

FY 2003 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to evaluate the capability of discriminating scrap that occurs within the top foot of the soil, using physics of the near field for magnetic unexploded ordnance (UXO) investigations. The theoretical analysis incorporated the geometric complexity of UXO and scrap, as expressed in the near-field, and built a database of results, which was expected to provide the basis for scrap discrimination. Although geometrical parameters were defined for specific shaped dipoles, these parameters cannot be recovered with sufficient precision to provide a reliable discriminator between UXO and scrap. Experiments provided an initial evaluation of the theoretical results on actual targets. In general, this approach seeks to reduce costs by recognizing and removing a specific subset of easily recognizable non-UXO signatures instead of finding a means of distinguishing the set of UXO signatures from non-UXO signatures.

BENEFIT: It is anticipated that these results will indicate that substantial reductions in scrap-based false alarms can be obtained by accounting for near-field effects. Experimental tests will demonstrate the principle of the method, as it could be applied in actual field operations and will form the basis for the future development of a field system.

ACCOMPLISHMENTS: In FY 2003, the numerical calculations for magnetic modeling scrap and UXO were set up. Testing of numerical results by comparison to known analytic solutions and modeling of the UXO were completed. The team generated models of spheres using different surface generation methods and investigated the accuracy of the calculated fields. The team also generated models of spheroids using different surface generation methods and in different orientations to investigate the accuracy of the calculated fields on planes at different heights above the models compared to the analytic dipole solutions for the same fields. The effects of different discretizations of the geometry and the accuracy of numerical integration on the accuracy of the solution were evaluated. The team determined that accuracy better than 1 in 105 can be achieved for the geometries. Finally, the team generated the geometry of a more realistic UXO-like conic model and investigated the fields at different heights above the model, in comparison to dipole fields.

TRANSITION: Upon demonstration of proof of concept, algorithms will require validation in a large scale real world demonstration. After the demonstration, the work will transition to the UXO contractor community.

PROJECT SUMMARY

PROJECT TITLE & ID: 3-D Geophysical Data Collection and Analysis for UXO Discrimination; UX-1357 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. T. Jeffrey Gamey, Oak Ridge National Laboratory, Oak Ridge, TN

FY 2003 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to create a practical basis for extension of geophysical techniques from two-dimensional (2D) to three-dimensional (3D) measurements to improve detection and discrimination of unexploded ordnance (UXO) targets. Existing geophysical field techniques already utilize “discrete” 3D elements by collecting vertical gradient magnetic data or multiple coil electromagnetic (EM) data. This approach is limited by 2D thinking and presentation (i.e., sensors are carried over the ground, readings taken at multiple heights are subtracted to produce a single parameter, and the results are forced onto a single planar grid at a nominal sensor height). Rather than measuring “discrete” 3D data and “forcing” it into 2D interpretations, the team proposed to extend the process to measuring “continuous” 3D data for 3D interpretation tools.

Digital geophysical mapping (in 2D over a standard grid) has evolved sufficiently to the point where it can be relied upon to detect UXO at most sites with enough accuracy to allow simple reacquisition. By modifying this process to cover the 3D space above an anomaly in a regular pattern and recording the sensor output and position with sufficient accuracy, this project provided the basis for more reliable inversion and analysis prior to excavation.

BENEFIT: This project demonstrated an innovative proof-of-concept that can be applied with available hardware. While care was required in the data collection, this approach made use of the lack of uniformity to enhance the results. The central innovation is a fundamental break from 2D thinking, control, and presentation of 3D phenomena. Recent advances in commercial navigation and tracking equipment will now provide instrument positions in three dimensions for small open areas to centimeter accuracy. By tracking the sensor position in three-dimensions with sufficient accuracy, and analyzing the data in an appropriate manner, the anomaly signature and its source can be represented and analyzed in its true form.

ACCOMPLISHMENTS: During FY 2003, synthetic models of dipoles were created in 3D to establish a baseline set of data for evaluation. Models were imaged in Geosoft (2D) and Rockware (3D). Several software routines were developed including a spherical dipole forward modeling code for one or more sources, a conversion routine from Geosoft to Rockware, a 3D analytic signal calculation for Rockware, a 3D gradient string calculation and presentation system for Rockware, and a color table manipulation routine for Rockware. Analysis of 2D data with noise added was completed. 3D and imaging were completed and followed by 3D data analysis.

TRANSITION: The techniques developed in this project and associated software will require additional work to reach a level of maturity suitable for field application. Additional modules for advanced filtering and inversion will need to be developed and tested with actual field data. The general concepts of 3D data acquisition and processing will be provided through public technical presentation and peer-reviewed papers. If appropriate, the software will be transitioned through commercial vendors who have the capabilities to market and maintain the product for the UXO market.

PROJECT SUMMARY

PROJECT TITLE & ID: Dual Mode Operation of GEM-3 as TD/FD Sensor; UX-1358 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. I.J. Won, Geophex, Inc., Raleigh, NC

FY 2003 COMPLETED PROJECT

DESCRIPTION: This project developed new operating software for the GEM-3 electromagnetic induction sensor that will run the sensor in both frequency-domain (FD) and time-domain (TD) modes. This was accomplished by interleaving TD and FD measurements. The unit time of one data collection operation is called "based period." In the simplest way, the GEM-3 worked in FD for one base period and in TD for another base period through a SW modification of the wave form. In this way, the sensor collected the FD and TD data at a sampling rate of 15Hz, which should be sufficient for most unexploded ordnance (UXO) surveys.

The project developed, implemented, and tested the dual mode operation. A major effort was aimed at developing algorithms for detection and discrimination of UXO using the dual-mode data. The system was evaluated for utility using data collected at a UXO test site.

BENEFIT: The GEM-3 broadband EMI sensor has demonstrated its potential for UXO/clutter discrimination. The GEM-3 has been operating as a FD sensor. However, the sensor and the accompanying electronics operate basically in TD. Combined FD-TD data from a single electromagnetic induction (EMI) sensor would provide challenging and exciting opportunities for new data interpretation schemes for UXO detection and discrimination. Application of the frequency-time domain sensor is expected to improve the UXO detection and discrimination capabilities of the GEM-3 EMI sensor particularly for deep targets.

ACCOMPLISHMENTS: During FY 2003, the GEM-3 performed and completed either an FD mode or a TD mode operation over a base period. The team completed an initial survey at the Geophex UXO test site. Using the operating software, the team conducted a separate FD and TD surveys. The team conducted additional experiments and surveys that improved the operating software and performed a limited discrimination experiment by combining the FD and TD data.

TRANSITION: At the completion of this work, Geophex will provide SERDP with all newly developed software and documentation. The software and data sets will be made available through SERDP to interested parties. If successful, these new and improved data interpretation schemes for UXO detection and discrimination would be further tested in a field deployment through funding sought from ESTCP. Ultimately, an improved instrument would be evaluated by Geophex.

PROJECT SUMMARY

PROJECT TITLE & ID: Model-Based, Robust Methods for UXO Discrimination from Time and Frequency Domain EMI; UX-1379

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Miller, Northeastern University, Boston, MA

FY 2004 FUNDS: $200K

DESCRIPTION: The safe and cost effective remediation of military sites containing buried unexploded ordnance (UXO), non-hazardous scrap, and other clutter requires that objects posing a threat be distinguished from those which do not. Those classified as dangerous are characterized in terms of size, shape, object type, and location prior to removal. Northeastern University (NU) addressed the problem of UXO discrimination in the SERDP Exploratory Development (SEED) project UX-1217, "A Unified Approach to the Processing and Fusion of Time and Frequency-Domain (FD) electromagnetic induction (EMI) Data for UXO Discrimination." Under UX-1217, physics-based signal processing methods were developed to distinguish clutter objects from UXO and classify the type of ordnance. The objective of this project is to complete the work started in the UX-1217 SEED project and transition it to the field. This project will: (1) refine and enhance the NU developed UXO discrimination signal processing algorithms; (2) develop a library of UXO time-domain (TD) and FD signatures; and (3) validate the algorithms using laboratory training data and field data collected in sufficient detail to be of use for the models and algorithms of interest in this work.

BENEFIT: The project is concerned with the synthesis and field-data validation of physics-based models and algorithms designed to substantially improve the ability to discriminate UXO from non-UXO items, thereby reducing the costs associated with the cleanup and remediation of Base Realignment and Closure (BRAC) sites, Formerly Used Defense Sites (FUDS), and other closed ranges. The processing methods are designed to optimally account for a large number of practical issues encountered in the field including: (a) lack of knowledge of the precise location and orientation of a buried object, (b) uncertainty in the position of the sensors during a survey, and (c) noise in the sensor data. Since the team can compensate for these effects within the context of a physically realistic, computationally tractable sensor model, the methods hold the promise of meeting the stringent performance requirements of the UXO remediation problem.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The algorithms in this project complement the current work being pursued by other UXO researchers. Additionally, the team will work with SERDP to deliver a database of sensor data along with documentation and validated software tools which will allow third parties to easily make use of and extend the methods developed.

PROJECT SUMMARY

PROJECT TITLE & ID: Advanced UXO Discrimination Using Magnetometry: Understanding Remanent Magnetization; UX-1380

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stephen Billings, Sky Research, Ashland, OR

FY 2004 FUNDS: $478K

DESCRIPTION: The magnetic remanence and advanced discrimination research performed under this project will address the efficient and reliable identification of unexploded ordnance (UXO) without the need to excavate large numbers of non-ordnance items. The fundamental objective of the project is to improve UXO discrimination performance and reliability by obtaining a better understanding of magnetic remanence in UXO and shrapnel. The team will develop magnetic remanence technology (MRT) used separately or in conjunction with electromagnetic induction (EMI).

The remanent magnetic characteristics of UXO and shrapnel will be researched. Mobile magnetometer systems for measuring magnetic remanence in the field will be developed. The magnetic remanence of ordnance pre- and post-firing at a test range will be measured. The magnetic remanence of UXO and shrapnel at two field sites will also be measured. A theoretical or empirical model of shock induced changes to magnetization will be developed. Test-stand data over ordnance will be collected. Finally, MRT methods will be incorporated into a workable software system.

BENEFIT: The technologies developed under this program will have significant positive impacts on DoD UXO clearance activities by facilitating deployment of new magnetic discrimination methods onto live UXO sites. Quantifying the extent of shock demagnetization under different impact scenarios will allow sophisticated UXO discrimination methods to be applied reliably across a wide range of DoD sites. The UXO false alarm rate (often quoted as contributing to 70% of the clearance cost) is the dominant financial factor that can be directly addressed by research and development. As such, technologies leading to routine field application of cost-reducing UXO discrimination methods are essential.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The involvement of Shaw Environmental and Infrastructure and Sky Research will provide direct transition of the technology into the industry. In addition, a final outcome of this project will be a software system for advanced magnetic discrimination that will be available to the wider UXO clearance community. This software system will be cooperatively developed through funding from the U.S. Army Engineer Research and Development Center (ERDC).

Transition of the technology to DoD sites will initially proceed through the direct involvement in this proposal of both the Montana Army National Guard and the U.S. Army Corps of Engineers (USACE) - Omaha District. As the need for advanced discrimination tools is DoD-wide, potential receivers of this technology also include other USACE Districts, the U.S. Navy, and the U.S. Air Force.

PROJECT SUMMARY

PROJECT TITLE & ID: Handheld UXO Sensor Improvements to Facilitate UXO/Clutter Discrimination; UX-1381

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Bell, AETC, Incorporated, Arlington, VA

FY 2004 FUNDS: $401K

DESCRIPTION: Research results have estimated that one of the most important factors in using unexploded ordnance (UXO) sensor data to characterize buried targets and discriminate between UXO and clutter is precise knowledge of sensor location and attitude while the data are being collected. This project will provide the means of obtaining that information with handheld UXO sensors. Handheld sensors are required for areas inaccessible by vehicle or man-portable systems because of terrain or vegetation. The objective of the project is to develop an inexpensive, robust way to precisely determine the position of a handheld UXO sensor as it is swept about a suspected buried UXO item.

The project entails integrating a compact, rugged inertial measurement unit (IMU) with a handheld UXO sensor. The integration involves the use of a hidden Markov model (HMM) to estimate the motion state of the sensor (turn or middle of sweep over target). Adaptive IMU noise suppression will be controlled by the HMM. The HMM will also control procedures for using the UXO sensor output as an external aid to the IMU to compensate for bias drift. A post processor will combine the position information from the corrected IMU with the sensor output stream to characterize the target and discriminate between UXO and clutter.

BENEFIT: The improved positional accuracy information of a handheld UXO sensor will enhance the sensor for use as a reliable UXO/clutter discrimination.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: At current retail prices, the IMU adds roughly 30% to the cost of a good handheld UXO sensor. Pressure from commercial applications is rapidly driving down the price of compact, rugged IMUs and the project team anticipates that within a few years the added cost will be less than $1,000. In transitioning the technology, the team will work with Geonics and/or Geometrics to integrate the IMU and processing into their handheld sensor systems. As it matures, the technology will be demonstrated and tested at ongoing commercial and defense cleanup sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Identification of Filler Materials in Unexploded Ordnance; UX-1382

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Wesley Cobb, University of Denver, Denver, CO

FY 2004 FUNDS: $188K

DESCRIPTION: Personnel who must remediate DoD sites need better tools to discriminate between unexploded ordnance (UXO) and non-hazardous items. Although great effort has gone to detect and localize UXO in the ground and underwater, there are currently few devices that can inspect and identify the filler materials. The ability to make a quick and safe identification would significantly lower the risks to personnel and the cost of remediation. In addition, to improve speed and safety, the filler identification method must be non-intrusive and operate while the ordnance item is partially or completely uncovered.

The project will utilize acoustic waves to identify the materials inside sealed UXO. Acoustic waves are high frequency pressure fluctuations (sound) that travel through materials. Small sensors clamped to the outside of the ordnance would send low-energy acoustic waves through the container walls and filler. The received signals would be processed to determine the characteristic acoustic properties of the filler material. To identify the filler, these measured properties would then be compared to a database of properties for known explosive and inert filler materials.

The project will first develop a measurement system and then test it on live and inert ordnance. Initially, research efforts will focus on the development of a test system that overcomes measurement problems caused by the corrosion and variability of UXO. A portable system will be developed and tested on both ordnance phantoms and live and inert ordnance items. Novel, high-precision electronic techniques will be used to measure the acoustic velocity and attenuation properties of the filler material. These methods rely on the propagation of an acoustic pulse at a single primary frequency through the case and filler material. Together with models of the acoustic propagation, this testing will provide initial indications of the reliability and discrimination capability of the technique. The acoustic technique will be further refined, and a modified measurement system will be tested on a wider range of ordnance items. Instead of making acoustic property measurements using a pulse with a single primary frequency, the refined method will use short time-duration burst (tone-burst) at many selected frequencies. This improved system will be tested on live (de-fused) ordnance to determine the improved accuracy of the measurements, and the resulting increase in identification reliability. At the end of this work, a new technology for UXO filler identification will be available for validation though subsequent field tests.

BENEFIT: A device based on this acoustic technique would permit personnel to quickly identify explosive and other hazardous items, and optimize subsequent verification. Improved safety and significant cost savings can be achieved through accurate identification of filler materials.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: Technology transfer will take place through development agreements with the Navy, DOE, or other government organizations. Financial support for device validation would be sought from ESTCP and leveraged by commercial instrument companies.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Analysis Algorithms for UXO Filler Identification; UX-1383

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Daniel Holslin, SAIC, San Diego, CA

FY 2004 FUNDS: $258K

DESCRIPTION: The PELAN (Pulsed ELemental Analysis with Neutrons) system is being developed and tested, with support from ESTCP and The Naval Explosive Ordnance Technology Division (NAVEODTECHDIV), for non-intrusively and quickly identifying the filler of unexploded ordnance (UXO) in situ for more cost-effective and safer environmental remediation.

In this project, the team will investigate, test, and demonstrate advanced data analysis and decision making algorithms for the PELAN system. The goals of these improvements are to increase the filler detection efficiency and accuracy, reduce false alarm rates, and improve the system's ability to learn the signatures of new targets.

Currently, in PELAN the critical elements are estimated using a linear signal model and a measure of the signal (sample) and background spectrum. A least squares fit is utilized to obtain estimates of the count rates of the various elements. The project team will investigate alternative signal models that may more accurately reflect the underlying physics associated with the sensing modality, investigate alternative spectral estimation procedures, and investigate statistical algorithms to more effectively process the count data. These lines of investigation will be pursued in three stages. In the first, or proof of concept phase, the team will apply pre-existing matching pursuits algorithms and generalized likelihood ratio decision algorithms to existing data sets to demonstrate the feasibility of the proposed approaches and to assess performance improvements over the techniques currently in use. In the second phase, remaining spectral estimation and statistical decision techniques will be pursued to determine which combination provides the most robust and optimal performance. Additional data collection will support training and testing. In the final phase, the team will transition the algorithms to the PELAN system and perform a field demonstration using these algorithms.

BENEFIT: The team will investigate, test, and demonstrate advanced data analysis and decision making algorithms for the PELAN system for non-intrusively identifying the fillers of UXO in situ for more cost-effective and safer environmental remediation. The goals of these improvements are to increase the filler detection efficiency and accuracy, reduce false alarm rates, and allow the system to be capable of learning the signatures of new targets.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The improved spectral analysis and decision-making algorithms developed in this project will be implemented directly into the current PELAN system and demonstrated to SERDP evaluators. Currently, the team is supported by NAVEODTECHDIV to adapt and optimize PELAN for the identification of UXO filler. The Navy has selected the PELAN system for acquisition in their Non-Invasive Filler Identification Program. NAVEODTECHDIV is interested in improving the analysis algorithms used in PELAN and is currently working with the researchers and ESTCP to collect additional data to evaluate the performance of PELAN and support algorithm development. The effort described here would transition directly to applications for identification of UXO filler for Explosive Ordinance Disposal (EOD), battlefield, and environmental remediation needs.

PROJECT SUMMARY

PROJECT TITLE & ID: Analysis and Processing of PELAN Data; UX-1384

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kurt Hacker, Naval Explosive Ordnance Disposal Technology Division, Indian Head, MD

FY 2004 FUNDS: $133K

DESCRIPTION: Prior to the selection of a disposal method for unexploded ordnance (UXO), a determination must be made of the filler material. These materials can range from standard military explosives, to chemical agents, to inert simulants. Currently, trained UXO experts perform this determination using external markings and visual examination. Many times the UXO has weathered or corroded, and the markings and external visual cues are deteriorated or absent. If a conservative approach is used and all questionable UXO is treated as an explosive or chemical filled UXO, the cost of clearance operations is greatly increased. If a less conservative approach is used, accidents may occur that lead to injury or loss of life. A means of rapidly and correctly determining the fill of UXO is needed to allow rapid deposition of inert rounds and proper handling of explosives of chemical filled UXO.

The Naval Explosive Ordnance Technology Division (NAVEODTECHDIV) has been investigating the use of the Pulsed ELemental Analysis with Neutrons (PELAN) developed by the University of Western Kentucky (WKU) and Science Applications International Corporation (SAIC) as part of the Office of Naval Research Applied Research effort. These efforts have demonstrated the utility of using PELAN to gather data from explosive, chemical, and inert filled UXO, but have highlighted the need for more advanced signal processing to increase the probability of detection and reduce the false alarm rate. NAVEODTECHDIV will address the important need of determining UXO filler material by utilizing improved, more robust decision support algorithms to analyze the output of the PELAN system.

The current PELAN system uses a decision tree algorithm that is based on WKU experience and prior knowledge of the UXO item under analysis. While this is feasible on a small number of well-understood targets, the utility for normal UXO operations is greatly diminished. The effort will apply neural network approaches to analyzing data that is currently being collected in the applied research and ESTCP efforts to demonstrate increased probabilities of detection and reduced false alarm rates. The goal of this analysis is to utilize the data collected during the PELAN tests to create a predictive model of the system. This model can then be used to test the true response of the system to new inputs.

BENEFIT: The application of new neural net algorithms will enable the PELAN to provide more robust UXO filler identification capability. This will extend the utility of the PELAN to general UXO operations where the target types are not known a priori. The current decision tree approach only works on a small number of UXO types and has shown unacceptable false alarm rates and probability of detection, particularly for smaller items.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The project teams expect the results of this work to improve PELAN detection and identification capabilities and will work with SAIC to implement the new algorithms transitioning them directly to industry. The UXO cleanup community will benefit from an improved system currently planned for evaluation at sites such as the Massachusetts Military Reserve (MMR). The improved algorithms will also be used as the basis for the transition to the Non-Invasive Filler Identification project sponsored by Project Management System-Explosive Ordinance Disposal (PMS-EOD). The PELAN has been chosen as the PMS-EOD Non-Invasive Filler Identification system.

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Properties and Capabilities of an Existing Experimental Large Loop EM61 Underwater UXO Detector; UX-1385

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peeter Pehme, Dillon Consulting Limited, Cambridge, Ontario, Canada

FY 2004 FUNDS: $100K

DESCRIPTION: In 2002, Dillon Consulting Ltd (DCL) undertook a reconnaissance-level marine unexploded ordnance (UXO) geophysical survey of Wright's Cove near Halifax, Nova Scotia, in water depths ranging from 2 to 70 ft. The objective was a statistical description of the distribution of metal on the seabed, based on approximately 5% coverage. This site presented challenges because of the depths involved. This project will build on the background that Wright's Cove provided, to address the problems it raised, and advance the state of the art.

The objective of this project is to determine if the limitations can be overcome and thereby produce a useful and simple system that can map UXO in water depths of 6-70 ft. The specific areas to be addressed are: (1) positioning and deployment of the receiver with respect to the transmitter and the seafloor; (2) understanding the system response by detailed calibration in terms of target size, salinity, water depth and system configuration; and (3) based on the calibration data, fine-tuning of the system electronics.

BENEFIT: This project directly focuses on providing a novel engineering-based technique and platform that overcomes access limitations for locating UXO present in underwater locations where the water depths range from 5 to more than 45 ft. Improving sensor and signal processing capability of an existing prototype system will quantify and improve detection and discrimination in underwater UXO-contaminated sites. If successful, this research will help provide cost effective UXO characterization in underwater environments.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: Geonics and DCL are receptors of this technology and will market it as appropriate. Geonics, as a marketer of equipment, will make it available to the community at large.

PROJECT SUMMARY

PROJECT TITLE & ID: Neutron Spectrometry for Identification of Filler Material in Recovered UXO; UX-1386

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mary Bliss, Pacific Northwest National Laboratory, Richland, WA

FY 2004 FUNDS: $100K

DESCRIPTION: Unexploded ordnance (UXO)-contaminated sites often include ordnance filled with inert substances that were used in dummy rounds. The DoD needs a reliable, timely, non-intrusive and cost-effective way to identify filler material. The Pacific Northwest National Laboratory (PNNL) will demonstrate that a portable neutron spectrometer, utilizing novel scintillating fiber detectors, is capable of distinguishing between inert and explosive filler material in UXO. Data generated from the project will be used to develop a preliminary design for a specialized, field-capable unit that can determine the contents of recovered, partially exposed, or near-surface UXO. This requires the use of a sealed radioactive neutron source.

PNNL's neutron spectrometer utilizes a novel neutron detector developed at PNNL. The detector greatly improves on the current He-3 based neutron detector designs, resulting in much smaller portable packages with quicker analysis times. Neutron spectrometry senses the relative hydrogen, carbon, nitrogen, and oxygen ratios in dense containers remotely and non-destructively. The technology is similar to devices used commercially to determine soil moisture, characterize oil wells, and measure asphalt quality.

A neutron source interacts with the target object, some neutrons are backscattered into a detector, and their energies are analyzed. The changes between the incident and backscattered neutron energies are determined by the relative hydrogen, carbon, nitrogen, and oxygen contents of the target. The data is then used to differentiate between inert filler materials and explosives.

BENEFIT: The project will provide new solutions to determine explosive hazards posed by unexploded ordnance by determining the content of UXO without fully excavating the item of interest. The project will develop proof-of-concept data for the design of a field neutron spectrometer based upon PNNL's scintillating fiber neutron detector. The neutron spectrometer will differentiate the relative hydrogen, carbon, nitrogen, and oxygen ratios in dense containers remotely and non-destructively, thereby allowing the contents of a UXO target to be chemically identified as inert or explosive.

The novel neutron detector is a leap forward in sensitivity and resolution that will facilitate development of a lightweight, low-power, safe operating, and quick-response spectrometer for identification of materials. The new technology is expected to enhance DoD's mission to remediate existing UXO-contaminated sites and to sustain active military training and testing ranges. The spectrometer will provide accurate data as to the content of unknown UXO devices improving removal efficiency and safety.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: The filler identification system developed in this project will be broadly applicable to many installations and sites that are currently contaminated by UXO. The resulting product will include a conceptual design for follow-on development of a prototype, which would involve close coordination with end users.

PROJECT SUMMARY

PROJECT TITLE & ID: Seismic Imaging of UXO-Contaminated Underwater Sites; UX-1387

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roland Gritto, Lawrence Berkeley National Laboratory, Berkeley, CA

FY 2004 FUNDS: $100K

DESCRIPTION: The objective of this project is to conduct a numerical modeling study to provide basic proof-of-principle that seismic imaging and scattering techniques can be used to detect unexploded ordnance (UXO) at underwater sites. Seismic scattering approaches can be applied to environments where strong contrasts between a host medium and an embedded anomaly produce reflected fields with strong amplitudes. The present case of UXO buried at underwater sites represents such a case, where the associated impedance contrast is roughly an order of magnitude larger than that associated with common seismic exploration targets (i.e., hydrocarbon exploration). The advantage of the scattering approach is that the dimension of the seismic wavelength can be chosen to be comparable to the size of the UXO, thereby maximizing the scattered seismic energy and resolution of the method. The numerical study will be based on single source-receiver pairs, 1-D linear arrays of the sources and receivers, and 2-D source and receiver arrays. The researchers will investigate whether beam-forming techniques can be utilized to increase the energy radiation into the sediments and how to focus energy onto the UXO target to improve the signal-to-noise ratio and to compensate for possible losses encountered in the shallow seafloor sediments.

BENEFIT: UXO presents a worldwide hazard in locations of previous military confrontations and at military training facilities. In particular, the presence of UXO in costal regions and at sites designated for base realignment and closure (BRAC) poses a severe risk that must be addressed before sites can be turned over to the public or costal areas made available for commercial traffic. Current costs of environmental cleanup of UXO are significant because of the large variety in UXO type and depth and the problems associated with distinguishing UXO from clutter. The development of innovative technologies for UXO detection will help reduce costs and environmental risks and enhance safety and health at sites designated for base realignment and closure. Presently there exists no effective capability to survey underwater areas, to successfully map the locations of UXO, and to distinguish them from clutter. Therefore, there exists an urgent need for reliable methods that work in marine environments.

ACCOMPLISHMENTS: This is an FY 2004 New Start.

TRANSITION: If successful, the technology will provide a prototype for the development of robust detection methods to locate UXO at underwater sites. Once the technology is developed, it can be implemented by environmental service companies or military personnel affiliated with cleanup at U.S. Navy sites and help to reduce the cleanup cost associated with shallow and deep water detection and recovery.

APPENDIX F
Statements of Need

This appendix contains brief summaries of all SERDP Statements of Need (SON) released in the past year. The objectives of SERDP are to support environmental research and development projects to meet high priority, DoD mission-related environmental needs. The "**Core**" solicitation occurs each year and provides funding in various amounts for multi-year projects. The smaller **SE**RDP **E**xploratory **D**evelopment, or "**SEED**," solicitation usually occurs annually and is a means for researchers to test proof-of-principle concepts. The SEED program is designed to provide support for high-risk, high-payoff projects in which funding is limited to a maximum of $100,000 for one year.

POLLUTION PREVENTION

UNEXPLODED ORDNANCE (UXO)

CORE STATEMENT OF NEED FOR FY 2005
CLEANUP – CUSON-05-01

REMEDIATION OF EMERGENT CONTAMINANTS

OBJECTIVE: The objective of this SON is to seek fundamental or applied studies to develop remedial alternatives for several emergent contaminants. Basic understanding of the mechanisms involved in contaminant destruction, either via chemical or microbial means, is needed in order to develop adequate remedial technologies. Consideration must also be given to common co-contaminants and how these co-contaminants impact degradation. Specific emergent contaminants of interest include 1,4-dioxane, N-nitrosodimethylamine (NDMA), and 1,2,3-trichloropropane (TCP). The research should focus on the following specific research objectives.

- Improved fundamental understanding of the mechanisms involved in degradation processes under varying natural and engineered conditions.

- Elucidation of the impact of co-contaminants on degradation processes.

- Improved understanding of the behavior of emergent contaminants under typical remedial technologies for co-contaminants. For example, 1,4-dioxane is a co-contaminant with chlorinated solvents; therefore, understanding the reaction pathway for 1,4-dioxane during monitored natural attenuation or enhanced anaerobic dechlorination would be critical.

- Development of remedial strategies for emergent chemicals, including consideration of the necessity for treatment train approaches to facilitate treatment of co-contaminants.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those involved in cleanup include developing appropriate remedial actions to address site contamination and treat the contaminated soil and groundwater to established cleanup standards. Chlorinated solvent and energetics contamination represents a considerable portion of contamination at DoD sites.

NDMA (C2H6N2O) is a product from the decomposition of unsymmetrical dimethyl hydrazine, a component used in the production of rocket fuel. This chemical is used as an additive in liquid propellant fuel for rocket engines. NDMA is used primarily in research (NTP, 2000), but it can also be formed inadvertently in a number of industrial processes. The EPA identifies NDMA as a probable human carcinogen (EPA, 1997).

1,4-Dioxane is used as a stabilizer for chlorinated solvents or volatile organic compounds. 1,4-dioxane has a high potential for entering the environment due to its volatility and solubility in water. Spent chlorinated solvents disposed of improperly can contaminate ground and surface water, and 1,4-dioxane has been detected in surface waters throughout the U.S. Exposure to small amounts of 1,4-dioxane may lead to significant adverse health effects. The primary routes of exposure include inhalation, ingestion, and dermal contact. The EPA has classified 1,4-dioxane as a Group B2, probable human carcinogen of low carcinogenic hazard.

TCP has been used primarily as a solvent and extractive agent. As a solvent, it has commonly been used as a paint and varnish remover, a cleaning and degreasing agent, and a cleaning and maintenance solvent. Releases to the environment are likely to occur as a result of its manufacture, formulation, and use as a solvent and extractive agent, paint and varnish remover, cleaning and degreasing agent, cleaning and maintenance reagent, and chemical intermediate. TCP is also used as a pesticide in formulations with dichloropropenes in the manufacture of D-D, a soil fumigant.

CORE STATEMENT OF NEED FOR FY 2005
CLEANUP – CUSON-05-02

TREATMENT AND RETAINMENT OF EXPLOSIVE- AND PROPELLANT-CONTAMINATED SURFACE RUNOFF FROM TRAINING RANGES

OBJECTIVE: The objective of this SON is to seek applied studies to develop innovative technologies capable of degrading explosive and propellant materials in surface runoff from DoD installations. Technologies should be applicable to large, potentially vegetated areas and should be directed to long-term control of energetic materials through self-sustaining treatment technologies such as phytoremediation or engineered wetlands. Periodic inputs of explosive and propellant materials will occur over the long-term and treatment technologies must be adaptable to unpredictable influxes of contaminants. Technologies may employ physical, chemical, or biological containment, immobilization, sequestration, or transformation approaches; however, the research strategy should focus on evaluating synergistic relationships among plants, microorganisms, and physical and chemical properties of the soil, which will allow for optimizing transfer and transformation processes.

The contaminants of primary concern are perchlorate (ClO_4^-) and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), due to their low federal health advisory level and their ability to migrate quickly through the soil matrix, but other explosive and propellant compounds and their breakdown products are also of interest. Research and development activities at laboratory-, bench-, and field-scale will be considered, but work does not necessarily have to culminate in a field-scale effort.

BACKGROUND: Significant quantities of soil have been contaminated at DoD installations as the result of military activities. Many of these sites are devoid of vegetation, in proximity to residences, and represent sites that are likely sources of continued off site migration of contaminants. Off-site movements of these contaminants to adjacent lands, aquatic systems, and groundwater may potentially have an adverse affect on humans and environmental receptors in an unanticipated manner. Therefore, concern about the environmental fate of explosives and propellants in soil, surface runoff, and groundwater from DoD installations/sites has compelled a nationwide focus on developing cost-effective remediation technologies.

Traditional methods of remediating contaminated soils, sediment, and water are often based on civil and chemical engineering technologies that have developed over the last 20 years. However, the application of some of these traditional treatment technologies to these areas and the massive amounts of contaminated water would be an enormous cost to DoD. Innovative technologies are needed that can function over the long-term with relatively low operational and maintenance costs.

CORE STATEMENT OF NEED FOR FY 2005
CLEANUP – CUSON-05-03

ECOLOGICAL SOIL SCREENING LEVELS AND WILDLIFE TOXICITY REFERENCE VALUES FOR IMPROVED RISK ASSESSMENT AT DOD SITES

OBJECTIVE: The objective of this statement of need is to collect data to assist in the development of ecological soil screening levels (eco-SSLs) for plants, invertebrates, and wildlife for any or all of the contaminants of potential concern and conventional receptor organisms following accepted methods. Proposals should focus on one or more of the following activities in order to fill gaps in the current knowledge base.

- Research producing data to support development of soil screening levels for: 2,4-dinitrotoluene; 2-amino-4,6-dinitrotoluene; 4-amino-2,6-dinitrotoluene; octahydro-1,3,5,7-tetranitro 1,3,5,7-tetrazocine (HMX); and nitroglycerin in plants and soil invertebrates.

- Research producing data to support the development of bioaccumulation factors to estimate contaminant concentrations in forage food to use in wildlife exposure risk models for: 2,4-dinitrotoluene; HMX; nitroglycerin; 2,4,6-trinitrotoluene; and RDX in plants, soil invertebrates, small mammals, amphibians, reptiles, and birds.

- Research producing data to support development of ecological toxicity reference values for both: (1) 2,4-dinitrotoluene; nitroglycerin; 2,4,6-trinitrotoluene; and RDX in birds, amphibians, and reptiles and (2) 2-amino-4,6-dinitrotoluene; 4-amino-2,6-dinitrotoluene; and HMX in mammals, birds, amphibians, and reptiles.

Contaminants listed above that are of particular concern and urgency include RDX, dinitrotoluenes (DNTs), and HMX. Proposers should focus on select groups of contaminants so that data is available to the risk assessment community in a timely manner. Research should be limited to collecting data that can be utilized by the Eco-SSL Workgroup to further develop an Eco-SSL for each respective contaminant. The specific species selected for wildlife studies may be at the discretion of the researcher; however, selected species should be applicable to the needs of the Eco-SSL workgroup. The Eco-SSL Workgroup is comprised of the EPA, together with other federal agencies, states, and industry groups.

Results from this work will provide knowledge and tools to allow DoD to cost-effectively characterize and predict environmental risk from contaminants of potential concern in soils. Currently, screening values are used for the metals and compounds listed above which may overestimate ecological risk during initial eco-risk screening and may result in costly and prolonged Baseline Ecological Risk Assessments. Completion of a validated set of Eco-SSLs following accepted methods for data quality objectives, experimental design, and test organisms will allow sites which possess concentrations of the listed contaminants of potential concern which fall below the Eco-SSL to assist in screening out specific substances and focus further study, thus resulting in cost savings. In addition, these data can be used in site-specific estimates of risk beyond the screen to provide risk managers with more accurate information from which to make decisions and hasten the closure/remediation of contaminated areas.

BACKGROUND: The EPA has developed a series of soil screening levels of contaminants of concern from available plant and soil invertebrate data, and has developed algorithms to develop wildlife-screening levels from known toxicity reference values. Eco-SSLs are used by the DoD during the completion of "screening level" ecological risk assessments to rapidly screen out sites which do not warrant further investigation.

CORE STATEMENT OF NEED FOR FY 2005
CLEANUP – CUSON-05-04

IMPROVED UNDERSTANDING OF IN SITU THERMAL TREATMENT

OBJECTIVE: The objective of this SON is to seek fundamental or applied studies to improve our understanding of: (1) the mechanisms of removal and destruction of free phase and residual dense nonaqueous phase liquids (DNAPLs) during in situ thermal treatment, including the reductions in plume loading and plume longevity; and (2) the impact of varying subsurface conditions on overall removal and destruction efficiency during thermal treatment. Results from these efforts should lead to: (a) an improved understanding of the potential of in situ thermal treatment for the removal and destruction of DNAPLs; (b) identification of the limitations associated with thermal treatment; and (c) development of improved application and monitoring methodologies.

Results of this research should directly support the DoD's goal to develop guidance for the use of thermal treatment. Guidance is needed on selecting thermal treatment technology for specific site conditions, selecting among the different technical approaches that are available, and incorporating thermal treatment into an overall site cleanup strategy. Modeling efforts will be considered only to the extent they build on experimental data developed during the research.

Development of a greater understanding of thermal treatment and improved methods for applying thermal treatment will facilitate the use of more cost-effective and efficient remediation technologies at DoD sites. Development of future guidance on the use of thermal treatment to remediate residual DNAPL source zones will help site managers select this approach where it is appropriate, and design and operate thermal treatment with greater confidence.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those responsible for cleanup include selection of appropriate remedial actions that will treat the contaminated soil and groundwater to established cleanup standards. Recently, there has been increasing interest in the use of technologies to remove/destroy contaminant source zones in situ. Remedial project managers are often faced with determining whether such technologies are appropriate for their site, yet little guidance exists for the selection and design of thermal treatment systems.

Thermal treatment increasingly is being tested and implemented at DoD sites because it is considered a rapid, although relatively expensive, method to remove and/or destroy contaminants, such as chlorinated solvents, in situ. There are several commercial approaches to implementing thermal treatment; however, as compared to other techniques, such in situ biological remediation, there has been little fundamental research on thermal treatment that could serve as the basis for guidance on the use of the technology. Significant questions remain regarding the impacts of site conditions on efficacy, the nature and fate of potential byproducts, the ability to collect representative multimedia samples, and any potential secondary impacts (e.g., volatile emissions, contaminant migration into cooler areas, problematic increased contaminant mobility, effects on biological activities, changes in geochemistry). In situ reaction rates and the environmental factors controlling those reaction rates are also not well understood.

CORE STATEMENT OF NEED FOR FY 2005
CLEANUP – CUSON-05-05

SCREENING LEVEL ASSESSMENT OF EXPLOSIVE AND PROPELLANT CONTAMINATION IN SOIL AND GROUNDWATER

OBJECTIVE: The objective of this SON is to seek applied research to develop innovative, rapid screening technologies to detect and delineate areas with soil or groundwater containing energetic contaminants including explosive compounds (RDX, HMX, 2,4,6-trinitrotoluene [TNT], DNT, etc.), propellants (ClO_4^-, etc.), and their byproducts. Identification and quantification of specific compounds is desired but is of secondary importance. This SON does not seek technologies for the detection of unexploded ordnance, but rather for detection of energetic chemical constituents in soil and groundwater.

The focus of this SON is to develop screening tools that will be used in the rapid, initial screening assessment of large DoD testing and training ranges in order to locate and delineate potential zones of soil or groundwater contamination that require more detailed follow-on characterization. Research and development activities at laboratory-, bench-, and field-scale studies will be considered. Work does not necessarily have to culminate in a field-scale effort.

Successful screening technologies will enhance the ability to perform cost-effective and rapid assessments of large areas within testing and training ranges to identify potential areas of energetic contamination.

BACKGROUND: There exists a growing concern that military training activities may lead to groundwater contamination on DoD ranges. One example of this situation exists at the Massachusetts Military Reservation (MMR). Military and law enforcement training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range and Impact Area lie directly over the Cape Cod Aquifer, which has been designated as a sole drinking water source for Cape Cod. The detection of energetic compounds in the groundwater beneath the Training Range and Impact Area demonstrates the potential for military training activities to cause groundwater contamination. There is a need to develop technologies to rapidly screen the millions of acres of DoD lands suspected of having soil and groundwater contaminated with energetic compounds. Technologies that permit stand-off, large-area screening would be advantageous.

CORE STATEMENT OF NEED FOR FY 2005
COMPLIANCE – CPSON-05-01

CHARACTERIZATION AND FATE OF THE SOURCE TERM OF ENERGETIC COMPOUNDS IN AQUATIC ENVIRONMENTS

OBJECTIVE: The objective of this SON is to solicit proposals to characterize the source term of energetic materials from munitions in aquatic environments and the resulting transport and fate of the energetic constituents. Specific issues to address include assessment of the potential for underwater fate and transport of such residues in freshwater, brackish water and salt water environments that are representative of DoD water training and testing ranges. The energetic materials include, but are not limited to, military explosive compounds such as TNT, pentaerythriol tetranitrate (PETN), RDX, and HMX as they occur in munitions. The energetic material itself, and any breakdown products, are all of interest. The specific goals of this SON are to: (1) develop energetic material source release functions that describe the mass transfer of solid phase energetic materials as found in munitions to a solute in aquatic environments and (2) provide predictive ability to assess the potential for migration or breakdown of residual energetic materials within aquatic environments. The interactions of the energetic materials with the aquatic as well as the sediment environment shall be explored.

BACKGROUND: Managing military ranges as a sustainable resource requires knowledge of the potential impact of energetic materials used in munitions. Developing basic scientific information on the potential sources, transport, and fate of energetic materials that come to reside in the aquatic environments, including fresh, brackish and salt waters is essential to a more complete assessment of the potential for environmental impact and exposure by those residual energetic materials that might be expected at military ranges as a result of the use of munitions. The research conducted under guidance of this SON is intended to contribute to the DoD's capacity to: (1) understand range environmental issues; (2) improve management of these critical aquatic resources; (3) assure the long-term viability of these key assets; and (4) facilitate compliance with current and proposed regulations.

Test and training activities can differ markedly in that testing is often intermittent and can involve unique materials, or materials that have not been characterized in detail and that may ultimately fail to become part of an inventory system. Such materials may result in residual energetic materials that could pose a potential for impact to the environment. In contrast, training activities involve the same munitions used in combat, and those munitions are used in larger quantities than in testing. In addition, specifically designed training munitions (often inert) are also employed in training. In summary, a broad range of munitions are used on military test and training ranges, and residual energetic materials from that use suggest there is a potential for environmental impact.

The potential for environmental fate impacts through the use of munitions in testing and training activities is not presently fully defined or understood. This is of concern in that knowledge of the expected composition, concentration, and distribution of residual energetic materials and their combustion and breakdown products, coupled with an understanding of the ability of these materials to migrate in the environment, are required in order to conduct detailed exposure or risk assessments. The scope of this SON is limited to conducting research to determine the amount and rates of release from sources and to develop environmental fate information for most of the energetic materials used in munitions. Only those factors and interactions dealing with energetic materials are the subject of this SON. The work shall explore the interactions with fresh, brackish and salt waters as well as various types of sediments, i.e., sand versus highly organic muds or muds that may contain high levels of iron.

CORE STATEMENT OF NEED FOR FY 2005
COMPLIANCE – CPSON-05-02

RANGE ENVIRONMENTAL FATE AND TRANSPORT EXPOSURE ASSESSMENT FOR ENERGETIC MATERIALS

OBJECTIVE: Military training and testing range managers require scientific information and management tools to ensure that these ranges can be managed in a sustainable fashion in the near and distant future. A major concern for live fire ranges is the potential transport and offsite exposure of energetic materials that are used by the military Services. The energetic materials of concern include: HMX, RDX, TNT, DNT, ClO_4^- and persistent daughter products. As part of an environmental risk assessment, an exposure assessment is performed using source data for each energetic material, the associated environmental fate (degradation), and transport by air and surface water to locations in or near the immediate area. While much work has been conducted to meet these needs, a number of data gaps remain. In addition, screening level modeling tools need to be developed to meet range managers' needs for assessing aquifer vulnerability, identifying contaminant source areas and determining when ranges need to be investigated, cleared and/or remediated or other management actions taken. The objectives of this SON fall into two main areas, environmental data and development of modeling/management tools.

Environmental Data - To date, a significant amount of environmental data on Army munitions has been collected. Data gaps remain regarding Army munitions and less is understood about munitions used solely by the Air Force and Navy. To complete the picture, SERDP is soliciting proposals to: (1) develop the environmental data required to characterize energetics residuals that result from the firing of Navy and Air Force munitions, including both characterizing potential sources and fate and transport; (2) develop the environmental data to characterize potential releases and fate of ClO_4^- as they occur on training and testing ranges; and (3) characterize residuals from gun propellants and characterize leaching rates of contaminants bound in these materials.

Modeling/Management Tools - Work also has progressed in recent years towards developing the fate and transport models required for exposure assessments. However, this work has not fully addressed assessments for energetic materials nor has it fully addressed the screening level tools needed by range managers. SERDP is soliciting proposals to address the following areas: (1) screening level tools are required to accurately and confidently predict aquifer and/or surface water vulnerability at training ranges based on site activities and site hydrologic/hydrogeologic characteristics; (2) modeling tools are required to link data for residual energetics in surface soils with groundwater data so as to aid in management decisions; and (3) tools that will enable range managers to determine if and to what extent ranges must be characterized, cleared or remediated based on the types of live-fire activities conducted and site-specific soil and climatic and hydrogeologic conditions and/or that can be used to determine the frequency of range clearance required to protect ground water. These tools must be based on scientifically defensible data to show in a probabilistic sense which activities pose risks and which do not, and be of value to range managers faced with weighing risks and management options in the face of uncertainty.

BACKGROUND: Managing military ranges as a sustainable resource requires knowledge of the potential impact of energetic materials used in munitions. Developing basic scientific information on the potential sources, transport, and fate of energetic materials is essential to assessment of the potential for environmental impact by those residual energetic materials that might be expected at military ranges as a result of the use of munitions. Research under this SON is intended to contribute to the DoD's capacity to: (1) understand range environmental issues; (2) improve management of these critical resources; (3) assure the long-term viability of these key assets; (4) facilitate compliance with current and proposed regulations; (5) meet future requirements for advanced weapon systems development; and (6) ensure the effective incorporation of these systems into new combat strategies needed to meet the defense requirements of the 21st Century.

CORE STATEMENT OF NEED FOR FY 2005
COMPLIANCE – CPSON-05-03

IDENTIFICATION AND CHARACTERIZATION OF NATURAL SOURCES OF PERCHLORATE

OBJECTIVE: The objective of this SON is to solicit proposals to identify and characterize potential natural sources of ClO_4^-. To date, most ClO_4^- found in ground water and surface water has been linked to anthropogenic sources (i.e., solid rocket fuel, energetics, fireworks, etc.) Due to the increasing concern over low levels of ClO_4^- in ground and surface water, it is important to understand both natural as well as anthropogenic sources. Limited previous research has identified ClO_4^- in a number of environmental samples which cannot be linked to an anthropogenic source.

Specifically the objectives of this SON are to: (1) identify the biological and/or geochemical processes that can lead to the formation of ClO_4^- under natural environmental conditions; (2) identify the potential mechanisms that can lead to accumulation or concentration of naturally formed ClO_4^- in the environment; and (3) identify soil and climatological conditions that could lead to the formulation and creation of ClO_4^-. Work at the laboratory or field scale will be considered. Proposals may be submitted that address any or all of the above objectives. Extensive environmental sampling to characterize a particular site will not be considered.

Results from this research will assist in the understanding of the presence of ClO_4^- as it may occur in the environment. This information will be used by DoD installations to make decisions when there is a need to provide water treatment. This work will result in a scientifically defensible evidence of the natural presence of ClO_4^- in the environment to prevent future liability.

BACKGROUND: ClO_4^- is the soluble anion used by the DoD since the 1940s as a critical component in military combat and training munitions including pyrotechnics, propellants, explosives, mines and rocket/missile fuels. Other uses of ClO_4^- salts in the chemical industries are in nuclear reactors and electronic tubes, as additives in lubricating oils, in tanning and finishing leather, as a fixer for fabrics and dyes, and in electroplating, aluminum refining, rubber manufacture, and production of paints and enamels. Concerns regarding the presence of ClO_4^- in the environment have grown since 1997, following its detection in the drinking water of more than 15 million people in the western U.S. ClO_4^- is highly persistent in the natural environment.

At present there is no national environmental standard regulating ClO_4^-. The EPA is considering a new standard for ClO_4^- in drinking water (on the low end of the 4-18 parts per billion (ppb) range that is under discussion). The State of California is considering a standard for ClO_4^- in drinking water of 2 to 6 ppb. The Commonwealth of Massachusetts has also stated that their level of removal for ClO_4^- from drinking waters on Cape Cod will be 1 ppb.

ClO_4^- has been found to occur naturally in the environment and is normally associated with certain nitrate deposits. The occurrence of these deposits in areas of California and Chile has raised the question as to the origin of the ClO_4^- in these areas and the possible levels to which treatment may or can be required for potable waters. The extent of these naturally occurring ClO_4^- deposits and the means by which they came into existence are not fully known and are therefore the subject of this SON.

CORE STATEMENT OF NEED FOR FY 2005
COMPLIANCE – CPSON-05-04

IMPROVED METHODS AND MONITORING SYSTEMS FOR IMPULSE NOISE

OBJECTIVE: The objective of this SON is to solicit proposals to improve methods for the monitoring and analysis of impulse noise. Specific attention should be focused on reducing the recording of false-positives, eliminating labor-intensive data analysis, improving diagnostic software, and providing the capability for date/time data queries, etc. Proposers are expected to understand the full range of noise emissions from military sources and the needed capability for noise monitoring systems. Proposers are expected to develop a cost effective solution to improve installation noise monitoring systems by (1) reducing false-positive events while maintaining accurate logging of real impulse noise events; (2) providing monitoring data in easily retrievable format, such as Microsoft Excel or Access; and (3) presenting monitoring data in an easy to understand manner which will facilitate public outreach.

The results of this project would provide a substantially improved system for monitoring impulse noise around DoD installations. The improvement of methods and monitoring systems will provide installations an accurate; less labor intensive and efficient means to manage testing and training impulse noise to verify or reject impulse noise complaints and damage claims. Current systems require time consuming and labor extensive data analysis.

BACKGROUND: Routine testing and training range operations can generate complaints and damage claims from civilian communities around DoD installations. These claims can result in testing and training restrictions and expenditure of funds for compliant and damage investigation, as well as damage itself.

The sustainability of testing and training ranges is a serious concern to the DoD. In 2000, the DoD Senior Readiness Oversight Council (SROC) examination of range sustainability identified nine key issues, one of which is noise associated with DoD training/testing operations. Most military installations were established in rural areas that were remote and isolated from population centers. Over time, this has changed as communities have developed and grown around these military installations. The sum effect has been that installations, once far from public view, are now often in the midst of densely populated areas. Noise is one of the inevitable consequences of military training practices and increasingly is becoming a concern for communities in the vicinity of these military installations.

Impulse noise is a short duration event (typically less than one second), of high intensity onset and rapid decay, and often exhibits rapidly changing spectral composition. Impulse noise is characteristically associated with such sources as explosions, impacts, the discharge of large caliber weapons (20mm or greater), and sonic booms. Impulse noise monitoring is an important tool for assessing noise impacts from military training and testing activity. Noise sources of concern include large guns (artillery, mortars and armor) and explosions (demolition charges, bombs, etc.). These sources have the majority of their acoustic energy at low frequencies, typically below 100 Hertz to as low as a few Hertz.

Wind impacts noise monitoring systems by inducing pressure fluctuations over a microphone or windscreen. These fluctuations produce signals with both temporal and spectral characteristics very similar to actual impulse noise events that result in thousands of false-positive events that obscure real events. This requires time consuming and labor intensive data analysis for individual event queries, self-diagnosis, web-based posting of monitoring data (public outreach), etc.

CORE STATEMENT OF NEED FOR FY 2005
COMPLIANCE – CPSON-05-05

TREATMENT OF PERCHLORATE IN WATER

OBJECTIVE: The objective of this SON is to solicit proposals to develop new, cost-effective, and innovative technologies and approaches for the removal of ClO_4^- from drinking water and waste water to levels to 1 ppb or less. Specific objectives include:

- Provide new, cost-effective, and innovative treatment technologies and approaches for removal of ClO_4^- from drinking water to 1 ppb or less. These technologies would be characterized by low capital and operating costs, simple operation, low energy consumption and minimal monitoring and maintenance.

- Provide new, cost-effective, and innovative treatment technologies and approaches to reduce or eliminate ClO_4^- from residual waste generated by drinking water treatment processes.

- Provide new, cost-effective, and innovative treatment technologies and approaches to reduce or eliminate ClO_4^- from waste waters generated by treatment processes.

Technologies and approaches should be applicable to a variety of water quality conditions. Research and development activities at laboratory-, bench-, and field-scale will be considered. Proposals are being solicited to specifically advance the state-of-the-knowledge for the treatment of ClO_4^- from drinking water and waste water generated from current drinking water treatment systems. Proposals to test and evaluate existing commercially available systems will not be considered. The purpose of this SON is to support development of new technology that shows potential cost advantages relative to existing technology.

Results of this research will assist in providing cost-effective treatment approaches for removal of ClO_4^- in drinking water, treatment residuals, and waste waters. These approaches should provide options for meeting any environmental standard that may be required in the future. This information will be used by DoD installations to make decisions when there is a need to provide treatment of ClO_4^- in water. In addition, the information will be used as guidance for the selection of a treatment technology on or off military installations. This work will result in scientifically defensible evidence of the efficacy of ClO_4^- treatment in drinking water to prevent future liability.

BACKGROUND: ClO_4^- is the soluble anion used by the DoD since the 1940s as a critical component in military combat and training munitions including pyrotechnics, propellants, explosives, mines and rocket/missile fuels. Other uses of ClO_4^- salts in the chemical industries are in nuclear reactors and electronic tubes, as additives in lubricating oils, in tanning and finishing leather, as a fixer for fabrics and dyes, and in electroplating, aluminum refining, rubber manufacture, and production of paints and enamels. Concerns regarding the presence of ClO_4^- in the environment have grown since 1997, following its detection in the drinking water of more than 15 million people in the western U.S. It is highly persistent in the natural environment.

At present there is no national environmental standard regulating ClO_4^-. The EPA is considering a new standard for ClO_4^- in drinking water (on the low end of the 4-18 ppb range that is under discussion). The State of California is considering a standard for ClO_4^- in drinking water of 2 to 6 ppb. The Commonwealth of Massachusetts has also stated that their level of removal for ClO_4^- from drinking waters on Cape Cod will be 1 ppb. Any technology developed must therefore meet the level of the Massachusetts standard until such time that a national standard is approved.

CORE STATEMENT OF NEED FOR FY 2005
CONSERVATION – CSSON-05-01

IDENTIFICATION OF VECTORS FOR TRANSPORT OF NON-INDIGENOUS SPECIES BY DEPARTMENT OF DEFENSE

OBJECTIVE: The objective of this SON is to solicit proposals to develop methods to identify and control the spread of non-native invasive species (NIS) that may be inadvertently transported by DoD vehicles and/or personnel. Part of this effort will be to obtain a better understanding of the role that DoD vehicular and personnel transport activities play in the introduction and spread of NIS. Research should focus on the extent to which military vehicles are able to transport invasive species in and around military installations as well as between installations. Research may also focus on methods to remove the invasive species from vehicles and personal gear prior to and upon return from deployment. Vehicles of interest include, but are not limited to, trucks, personnel carriers, tanks, and amphibious vehicles.

Proposals responding to this SON should address one or more of the following objectives: (1) identify transportation vectors for the introduction and spread of NIS; (2) determine the most significant transport vectors both within the continental United States (CONUS) (between and within installations) and outside CONUS (OCONUS) (both departing for and returning from overseas deployments); and (3) develop and/or improve methods of cleaning and NIS removal from equipment and personnel prior to transportation other than brushing and washing with water. The cleaning methods identified for NIS removal, destruction, or containment should be as general as possible in order that a few methods can be used for several or many NIS and should not produce significant hazardous waste streams.

BACKGROUND: During war, peace-keeping missions, and regular training activities, it is necessary for troops and their equipment to deploy to regions across the globe. In addition, for military personnel to train as they will need to fight, it is often necessary to transport both troops and vehicles to installations across the country. Each and every time troops deploy, there is a high likelihood that plant, animal, and pathogen "hitch hikers" may also tag along. Current inspection and wash facilities do not catch and eliminate all of these unwanted organisms.

Vehicular and personnel transport activities on military lands frequently result in the transport and spread of NIS such as ants, grasses, and shrubs. The case of the brown tree snake is the most high profile example of this phenomenon, but far from the only one. For example, in Hawaii, expanded off-road use associated with expanded and new military training poses a significant potential threat to 22 endangered snails, 4 endangered birds, and more than 80 threatened and endangered plants that reside on military reservations in Hawaii. NIS are the second leading cause for species endangerment, following direct habitat destruction, and their spread poses a significant threat to military training lands.

Transport of personnel and equipment both within the country and internationally can result in the inadvertent transport of NIS. Currently, U.S. Department of Agriculture (USDA) has responsibility for inspection for cargo and materiel entering U.S. ports. Of the total amount entering the country, USDA inspects only a fraction. In addition, they do not inspect interstate cargo. Thus, responsibility for controlling the transport of NIS on DoD material lies with DoD. The Armed Forces Pest Management Board Technical Guide 31 provides guidance for current DoD wash down procedures.

Finally, Executive Order (EO) 11312, signed by President Clinton in February of 1999, requires federal agencies "to prevent the introduction of invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause." In response to EO 11312, the National Invasive Species Council has developed a management plan and other reports that are relevant to NIS pathways identification, early detection, and prevention.

CORE STATEMENT OF NEED FOR FY 2005
CONSERVATION – CSSON-05-02

DEVELOPMENT BY AN ADVANCED MONITORING STRATEGY FOR MIGRATORY BIRDS ON MILITARY LANDS

OBJECTIVE: The objective of this SON is to solicit proposals to determine the fundamental relationships of various environmental elements that define migratory landbird habitat and routing, and to understand how these elements contribute to bird distribution and abundance and can lead to improved monitoring strategies.

Proposals responding to this SON should address one or more of the following objectives: (1) determine the relationships of unique environmental features or properties and their contribution to the presence, distribution, and abundance of migratory birds on DoD lands; (2) develop new or improve existing migratory landbird monitoring methods that are scientifically rigorous, reliable, and relevant to the military; and (3) forecast the presence and abundance of migratory birds on DoD lands based on ecological factors, habitat, and/or other aspects of their natural behavior. The use of any existing data sets for initial studies is preferred. When feasible, the use of existing and available ecological analytical models (rather than the development of new models) to accomplish a similar purpose, is also preferred. Models and other software must be compatible with the DoD Partners in Flight (PIF) database.

BACKGROUND: There is a paramount need for a comprehensive, integrated avian monitoring program. DoD natural resource managers need to know the answers to such questions as what species occur on individual installations, what management needs exist for those species, what monitoring techniques and protocols work best for each species, and what percent of a species population exists on military lands.

Currently, there is no comprehensive strategy for when and how to monitor migratory birds on military lands. When monitoring is carried out, the resulting information may not provide an accurate answer to relevant management issues. This lack of coordination and standardization of migratory bird monitoring programs on military lands has meant that the information from individual monitoring efforts frequently is not used at the regional and range-wide levels, for example in listing and delisting decisions, defining bird conservation goals, and evaluating management actions. Furthermore, biologists at the local level are often uncertain what large-scale goals are most important, what field and analytic methods to use, where to submit data for permanent storage, and, in general, how to ensure that their work is combined with the work of others in an effective manner. DoD needs to document a strategy for migratory bird management on military lands, in a way that supports the military training mission while meeting all legal obligations. All efforts should be closely coordinated with U.S. Geological Survey's (USGS's) Biological Resources Division.

The U.S. Fish and Wildlife Service (USFWS) Birds of Conservation Concern 2002 (BCC) lists birds that are not threatened and endangered but are of concern to land managers. Discussions with USFWS regarding Migratory Bird Treaty Act (MBTA) issues are being focused on BCC species. DoD Partners in Flight program has begun the task of compiling a database to document which BCC species exist on installations throughout all USFWS Regions (50 states, Puerto Rico, Pacific Island sites). In addition, a DoD Bird Conservation database is under development to provide a central repository for all bird-related projects and data related to military lands. These databases can provide the basis for documenting the needs of migratory birds and provide answers to future inquiries involving MBTA or "take" issues.

CORE STATEMENT OF NEED FOR FY 2005
CONSERVATION – CSSON-05-03

DEVELOPING TERRESTRIAL BIOGEOCHEMICAL CYCLE MODELS FOR FT. BENNING ECOSYSTEMS

OBJECTIVE: The objective of this SON is to solicit proposals to develop models for biogeochemical cycles that (1) contribute to an overall understanding of ecosystem dynamics and (2) enable development of nutrient availability thresholds that can assist land managers in determining appropriate land uses and land management approaches for ecosystems associated with Ft. Benning, Georgia (on the installation and within the surrounding region). The biogeochemical cycles of primary interest are carbon (C) and nitrogen (N) and their interactions relative to nutrient resource thresholds. Other nutrient cycles, such as that of phosphorus (P), do play roles in these interactions and may be of particular importance on certain soil types and for particular ecosystem types. Proposed research may address the P cycle, but will need to justify the benefits of such research relative to the ecosystems of interest under this solicitation and their nutrient dynamics and thresholds.

The relationship of land management practices, both on and off the military installation, to the above nutrient cycles is a key factor in any proposed work. On-installation land use and management activities include a range of differing: (1) military mission usage levels (e.g., current, decreased, increased); (2) forestry practices (e.g., thinning/harvesting, planting, and prescribed burning), and their potential variation in implementation that may affect biogeochemical cycling (e.g., frequency and intensity of prescribed burning, differing timber harvesting and management regimes); (3) land cover types and their desired end-states; and (4) ecosystem management goals (e.g., longleaf pine [Pinus palustris Mill.] ecosystem restoration, military training land sustainability, etc). Off-installation land uses include urban development, agriculture, and commercial forestry.

To improve our understanding of biogeochemical cycle dynamics and associated nutrient resource threshold model development, the proposers would need to conduct efforts in two phases. The first phase will be to develop a conceptual model. The second phase involves the development of a quantitative model and the relationship of this model to land use and management goals and activities at Ft. Benning.

BACKGROUND: In 1997, the SERDP Program Office sponsored a workshop entitled Management-Scale Ecosystem Research. The workshop attendees, which included many leading academics in ecosystem management as well as several DoD staff, examined the feasibility and value of conducting ecosystem research on DoD facilities, and identified a set of key research themes that would both contribute to DoD operations and to ecosystem management science. After this workshop, SERDP established a new project, entitled the SERDP Ecosystem Management Project (SEMP). SEMP research has produced substantial data on productivity and carbon components of the ecosystems. Current research and monitoring activities at Ft. Benning, through the SEMP project and other efforts, are generating productivity and biomass data to be used to derive "threshold" and "indicator" measures for ecosystem management purposes. The primary data also have value for a combined C and N cycle analysis. Moreover, all these factors (i.e., threshold, indicator, productivity, N cycle, C cycle) contribute environmental information for site management decisions. The C and N cycle integration is also expected to provide protocols and framework for guiding similar assessments at other installations.

Ongoing research at Ft. Benning has contributed to our knowledge of various portions of biogeochemical cycle dynamics in longleaf pine and bottomland hardwood ecosystems. However, many data points are still lacking with respect to the role of nutrient cycles and nutrient availability in determining threshold responses for plant community function and sustainability in managed landscapes.

CORE STATEMENT OF NEED FOR FY 2005
CONSERVATION – CSSON-05-04

IMPROVED REMOTE SENSING TECHNOLOGIES FOR DETECTION OF THREATENED AND ENDANGERED SPECIES AND THEIR HABITAT

OBJECTIVE: The objective of this SON is to solicit proposals to develop new remote sensing technologies to detect high priority threatened and endangered species (TES) and their habitat(s) on DoD lands. Of particular interest are those TES that are inaccessible (e.g., in burrows or hidden roosts) during certain life stages or during part of the day/night. It is anticipated that the techniques developed pursuant to this SON will result in reduced costs and/or improved accuracy of the detection of high priority listed species and their habitats.

Proposals responding to this SON should address one or more of the following objectives: (1) develop remote sensing technologies to identify TES that are generally inaccessible or difficult to locate during field investigations and (2) develop remote sensing technologies to identify TES habitat that may be inaccessible due to rugged or off-limits terrain (e.g., due to constant use or unexploded ordnance [UXO] issues).

For the purposes of this SON, "high priority" species are identified as those that are currently causing, or have significant potential to cause, impacts to the training and testing mission of DoD installations. Species that meet the definition of high priority for the purposes of this SON include, but are not limited to, Indiana bat, gray bat, desert tortoise, flat-tailed horned lizard, and flatwoods salamander. For bat species of interest, remote detection of cave and mine entrances are of high interest.

BACKGROUND: Many wildlife species and even the habitats those species occupy can be difficult to observe and study. Specific difficulties related to military lands include, but are not limited to, (a) remote and/or nearly inaccessible location (e.g., due to constant use or UXO issues); (b) potentially wide range; (c) sparse and/or low species density; (d) nocturnal or other habits/life history; (e) cryptic and/or similarity of appearance to other species; (f) inaccessibility of dwelling places/habitat; (g) small size; and (h) seasonality.

A short list of examples of problems and needs include those associated with or related to chiropteran habitat and life history (e.g., bat roost locations), subterranean species (e.g., gopher tortoise and other burrow dwelling species), cave species (e.g., bats, fish and arthropods), and species with general knowledge gaps (e.g., mortality factors in "western" sage grouse).

Many bat species, including listed and candidate species, depend on suitable and secure roosting habitats that only certain caves or mines provide. Roost locations may be remote and widespread across the landscape, while entrances may be small, inconspicuous, and inaccessible. Mapping locations of caves and roosts that may provide bat roost habitat, or habitat critical to life histories of other listed species, would increase the efficiency and effectiveness of field surveys, environmental assessment and conservation of biodiversity.

Developing new technologies is needed so that crucial species and habitat related information, much of it currently unknown, can be provided to resource managers and scientists. These technologies may include those broadly categorized as "remote sensing," which could be applied to identify and examine individual or groups of species or their habitats from afar. These technologies may include a full range of optical, thermal, movement, electronic, acoustical, chemical, or mechanical tools/sensors/approaches that provide information on species and their habitats which is either unknown or unobtainable. Given the specialized and varying life histories and life history requirements of many species of interest, developed or applied technologies or methodologies may be relatively species-specific.

CORE STATEMENT OF NEED FOR FY 2005
POLLUTION PREVENTION – PPSON-05-01

HAP-FREE SOLVENTS FOR DOD HAND WIPE CLEANING APPLICATIONS

OBJECTIVE: The objective of this SON is to develop a zero Hazardous Air Pollutant (HAP), low Volatile Organic Compound (VOC) solvent or family of solvents suitable for hand wipe cleaning operations in DoD maintenance facilities. It is anticipated that many of the most commonly used HAP solvents will be banned in the near future and that the mission capability of systems under acquisition will be impacted by the availability of low VOC/zero HAPs cleaning solvents. The DoD has a coordinated plan to address the requirement for qualified replacements for National Emission Standards for Hazardous Air Pollutant (NESHAP) regulated solvents that includes short-, mid- and long-term goals. The goal of this solicitation is to address long term objectives for the development of alternative cleaning materials produced from environmentally benign chemistries and not to focus on short- term process alternatives. The goal of this SON is to address industrial hand wipe cleaning applications and alternative cleaners for janitorial use are excluded. Approaches based upon the use of supercritical CO_2 are specifically excluded from this solicitation.

Proposed cleaners should be HAP-free, to insure compliance with all surface coating NESHAPs, and be effective in removing a variety of soils (e.g., water-based machine tool coolants, hydrocarbon-based machine tool lubricants, waxes, greases, oils, salts, sand, and grit). For the solvent to be implemented nation-wide in the next ten years, the maximum permissible concentration of VOC is 50 g/l, with a target VOC concentration of 25 g/l (based on California South Coast Air Quality Management District rules).

BACKGROUND: The pending Defense Land Systems & Miscellaneous Equipment (DLSME) NESHAP limits the use, storage and disposal of HAP containing cleaning solvents. There are also other federal, state and local laws and regulations that limit the use, storage and disposal of cleaning solvents due to their classification as hazardous, flammable, and toxic substances. The DoD Services rely on these solvents for the manufacture, remanufacture, repair, maintenance and inspection of their systems.

There have been numerous technology initiatives across the DoD to reduce dependence on VOCs and to eliminate hazardous emissions from cleaning solvents. DoD solvent surveys for CY 2001 found that hand wipe cleaning operations are still the most pervasive cleaning operation in the DoD and represent the largest quantity of VOC/HAP containing solvents used in cleaning applications. The existing NESHAPs for Aerospace and Shipbuilding regulate coatings “as-applied.” The Miscellaneous Metal Parts and Products (MMPP) and the Plastic Parts and Products (PPP) NESHAPs regulate HAP emissions from the entire coating process which includes the sub-tasks of cleaning, degreasing, paint stripping, painting, cleaning between coatings, adhesives, stenciling and marking and post painting clean-up. There are no exemptions provided and they regulate based on the quantity of solids applied. The DoD actively participated in the development of the Shipbuilding and Aerospace NESHAPs and was satisfied with the emission limits contained in the final rules. However, no one anticipated the enormity of the record-keeping burden which this entailed until after actual implementation of these NESHAPs.

There are three alternatives to address the mission risk and cost burdens associated with these NESHAPs: (1) pollution control, (2) pollution prevention, and (3) the elimination of painting and bonding operations at DoD facilities. Cleaning operations are the most influential factor in compliance, and pollution prevention provides the greatest opportunity to impact this issue. In general, solvents that are suitable for wipe cleaning will also find utility in immersion cleaning, flush cleaning, and dipping/spray/vapor degreasing applications as well. The availability of a low VOC, zero HAP wipe solvent will not only reduce emissions but will also provide significant payback in terms of reduced costs associated with NESHAP mandated record keeping and reporting.

CORE STATEMENT OF NEED FOR FY 2005
POLLUTION PREVENTION – PPSON-05-02

ALTERNATIVES FOR PERCHLORATES IN INCENDIARY MIXES AND PYROTECHNIC FORMULATIONS FOR PROJECTILES

OBJECTIVE: The objective of this SON is to develop environmentally benign, ClO_4^--free incendiary and pyrotechnic mix technologies for projectiles. The focus of this SON is to eliminate potential future ClO_4^- soil, surface water and groundwater contamination from training and testing of munitions as well as from production and disposal of these munitions. Proposed technologies must be capable of meeting or exceeding current DoD-required safety and performance criteria. This includes, but is not limited to toxicity, stability, sensitivity, ignitability, hygroscopicity, candle power, and burn time. Human health and ecological considerations during the lifecycle of the incendiary mix and during ingredient manufacture must be addressed. As a secondary objective, the proposed alternative must still be visually scoreable but should reduce the propensity for hot spots and brush fires on training ranges. Current formulations have an average heat value of 2Kcal/gram.

In addition, the following guidelines must also be considered: (1) the production of the alternative pyrotechnic system must have the potential to be more environmentally benign than the current ClO_4^--based production processes; (2) the presence of unburned residues, such as may be found in test and impact areas must be environmentally benign; (3) the combustion products must be environmentally benign; (4) anticipated future tracer cost should be competitive with current systems; and (5) proposals offering alternatives that reduce the propensity of the device to cause brush fires will be judged favorably.

BACKGROUND: ClO_4^- are used as an oxidizing component in some of the incendiary mix formulations and flash compositions used in projectiles. These formulations are used as markers to produce an incandescent flash (and smoke) to mark the impact point, as ignition sources for flammable liquids, and as igniters to initiate explosive trains on impact. ClO_4^- are extremely soluble in water, mobile in subsurface aqueous systems and may readily contaminate surface and ground waters in and around manufacturing, processing, and testing facilities if released. ClO_4^- are chemically stable and may persist for decades under typical ground water and surface water conditions.

In early 1997, the California's Department of Health Services (DHS) Drinking Water Program first found inorganic ClO_4^- in some drinking water wells in northern California. Since then, inorganic ClO_4^- have been discovered in the ground waters and surface waters in several states, including northern and southern California, Nevada, Arizona, Utah, and Texas. The majority of the locations are in California, and may be associated with formerly active facilities that manufactured, tested, or demilitarized solid rocket fuels and other ordnance items for the Defense energetic materials community. It has been estimated the ClO_4^- contamination of groundwater impacts 12 million people in the states of Nevada, California, and Arizona. ClO_4^- contamination is of great concern because of its ability to disrupt the endocrine system by inhibiting iodide anion uptake by the thyroid. The mounting weight of the evidence of the extent of ClO_4^- contamination and the potential human health effects, have prompted EPA to propose the addition of ClO_4^- to its Contaminant Candidate List.

ClO_4^- contamination can occur during several phases of the munition lifecycle. It can occur during the manufacturing of ingredients, the mixing of formulations, the assembly of products, the use of the product during testing or training, or during the demilitarization of the product. The development of alternative formulations without ClO_4^- can address all modes of contamination for a specific ordnance item life cycle.

CORE STATEMENT OF NEED FOR FY 2005
POLLUTION PREVENTION – PPSON-05-03

ENVIRONMENTALLY BENIGN MEDIUM CALIBER GUN BARRELS

OBJECTIVE: The objective of this SON is to develop environmentally benign (hexavalent chromium [Cr^{+6}]- free, low VOCs, low HAPs) techniques/materials/processes to protect medium caliber (20mm to 40mm) gun barrels bores from in-service wear and erosion. Proposals shall include testing to measure the performance capabilities of the resulting coatings and/or liners. These tests should include, as a minimum: (1) erosion studies in realistic configurations with actual propellant gases, (2) thermal cycling from room to maximum in-bore temperatures followed by a water quench, and (3) adhesion of the coating/liner materials. Relatively mature approaches should also include test firing studies to evaluate: (a) gun bore erosion, (b) firing accuracy, and (c) rifling durability issues. System performance shall meet or exceed that of the current systems. Additional technical elements that must be addressed include, but are not limited to, cleaning or surface preparation treatments and corrosion protection if appropriate. Approaches which require modification of the ammunition are specifically excluded from this solicitation.

The benefit of this work will be the elimination of the dependence on electrodeposited Cr^{+6} to prolong the life of medium caliber gun barrels and a reduction in the use of VOCs and HAPs for this application.

BACKGROUND: Medium caliber gun barrels (20mm to 40mm) use chromium as a protective coating on their interior bore surfaces to resist damage from hot propellant gases, thermo-chemical effects and the mechanical effects of the projectiles passing through the bore. Current coatings are electro-deposited from aqueous solutions of Cr^{+6}. While chromium is very effective in this application, Cr^{+6} is a known human carcinogen that is strictly regulated. The Occupational Safety and Health Administration (OSHA) regulates the amount of Cr^{+6} to which workers can be exposed, and has proposed reducing the Permissible Exposure Limit (PEL) for Cr^{+6} from the current 50 micrograms per cubic meter ($\mu g/m^3$) to less than 1 μg/m3. OSHA's proposed PEL will severely impact the use of Cr^{+6} throughout DoD. New coating or liner technologies are required to prolong the life of these medium caliber weapons. Current projections for production quantities of 20mm, 25mm and 30mm guns over the next 9 years exceeds 39,000 units and production costs exceed $45 million.

Internally magnetized, cylindrical magnetron sputtering has been demonstrated to be capable of depositing chromium-free coatings to protect large caliber gun bores. Initial performance coating cylinders with internal diameters of 60mm and greater has been satisfactory. However, the deposition technique does not perform well below 45mm because the smaller bore diameters of medium caliber guns cannot accommodate the critical ionization distance required for this process. The ionization and deposition processes become unstable. As a result, proposals that may be based upon the use of internally magnetized, cylindrical magnetron sputtering must include specific information to address these shortcomings.

SEED STATEMENT OF NEED FOR FY 2005
POLLUTION PREVENTION – PPSEED-05-01

ALTERNATIVE TECHNIQUES TO UNIQUELY IDENTIFY INERT MUNITIONS

OBJECTIVE: The purpose of this solicitation is to develop techniques to unambiguously identify expended target/practice rounds to facilitate range clearance and ordnance demilitarization. Practice bombs and other training ordnance items which contain no energetic ingredients are easily identified, as manufactured, because they are clearly marked. However, these identification markings are often no longer legible when it becomes necessary to clear training and practice ranges. As a result, it is necessary to treat any detected (buried or exposed) expended target/practice rounds, which cannot be clearly identified as inert, as an UXO item and to dispose of it accordingly. The purpose of this solicitation is to develop alternative materials and/or designs or techniques which reduce or eliminate the possibility of misidentifying inert practice rounds as UXO. Proposals should address ballistic performance and the ability to score training performance. Proposed solutions must be compatible with DoD weapons platforms.

The benefit of this work will be a reduction in uncertainty in the identification of expended ordnance. This will simplify clearing UXO from ranges and reduce hazards associated with disposal of practice/training rounds.

BACKGROUND: The UXO 2001 Report to Congress estimates that over 11 million acres of property in the U.S. may be contaminated with UXO. This includes approximately 763 Formerly Used Defense Sites (FUDS) and 23 Base Realignment and Closure (BRAC) installations which must be cleared of UXO for DoD reuse or civilian use. A combination of political, regulatory and budgetary drivers forces the need to improve the DoD's ability to more effectively remediate UXO sites. In addition to the need to clear inactive ranges, all munitions residue must be removed from the surface of targets on active ranges to sustain them for use. Buildup of debris causes ricochets and ruins the target's value since massive buildup of scrap and trash is surprisingly visible from the air. Explosive Ordnance Disposal (EOD) personnel are responsible for the determination of energetic hazards and, when in doubt, items are demilitarized, blown in place. Only items which are too dangerous to move are destroyed in place. Many practice munitions, if they are clearly identified, may be moved to a single on-range point for demolition with a degree of safety if processes are in place to handle and transport live items safely. For example, dud BDU-33 practice bombs are loaded into a dump truck. The dump truck offers protection to the person placing the bomb into it should the spotting charge explode. White Phosphorous warheads, on the other hand are blown in place because they are much more energetic and too dangerous to handle. All items recovered from the range are considered explosive contaminated scrap and must be inspected for explosives according to DoD and respective Service directives. All munitions are required to be demilitarized by opening them to expose their interior cavities to visual examination, and all inert bombs must be vented to expose their inert fillers before they are offered for salvage.

CORE STATEMENT OF NEED FOR FY 2005
UNEXPLODED ORDNANCE – UXSON-05-01

SITE CHARACTERIZATION AND REMEDIATION TECHNOLOGIES FOR UNEXPLODED ORDNANCE (UXO)-CONTAMINATED UNDERWATER SITES

OBJECTIVE: The objective of this SON is to develop technologies to support characterization and/or remediation actions for unexploded ordnance found on underwater sites. Research and development proposals should focus on one or more of the following activities: (1) novel, engineering-based techniques or platforms that overcome the access limitations for locating UXO present in underwater locations (e.g., coastal areas, marine sediments, harbors, estuaries, lakes, ponds and wetlands); (2) improved sensors or signal processing to aid in detection and discrimination in underwater UXO-contaminated areas; (3) improved supporting technologies for navigation and geolocation of underwater platforms; (4) characterization and phenomenology of underwater UXO, including migration and depth of burial in various underwater environments; and (5) removal and disposal techniques for underwater UXO.

Modern geophysical surveying techniques can effectively be used to characterize sites potentially contaminated with UXO on dry land. For easily accessible sites where signatures are sparse and anomalies are spatially isolated, these tools can guide detection-driven remediation activities, and in some cases, can effectively screen clutter from ordnance. However, many sites contain UXO underwater, where the environment restricts established and emerging characterization and remediation alternatives. To direct remediation efforts appropriately and to clean underwater UXO areas reliably, SERDP intends to develop techniques that provide reliable target detection and discrimination, and remediation tools that can cost effectively and safely remove or dispose of UXO. The primary interest of the program is to address UXO that is accessible to people and presents a potential hazard.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for BRAC and at FUDS. Particularly difficult is the characterization and remediation of those sites where UXO is found in underwater environments. Presently, there exists: (1) no effective capability to survey these underwater areas and map the location of UXO for site characterization, (2) little understanding of the UXO or clutter characteristics from which to establish performance requirements, and (3) limited removal and disposal techniques that could be expanded or improved. Factors such as small target size, target burial, shallow water, environmental noise (as from surface waves and reverberation), and water turbidity all impact sensor performance, while the submerged nature of the UXO impedes access.

Many active and former military installations have ordnance ranges and training areas that include adjacent water environments such as ponds, lakes, rivers, estuaries, and coastal ocean areas. Wartime activities, dumping, and accidents have also generated significant UXO contamination in the coastal and inland waters in the U.S. and abroad. Dredging projects frequently encounter UXO.

The problem of underwater UXO contamination has commanded more attention in island and coastal nations overseas than in the U.S. In these countries, where the ratio of underwater land area to surface land area is higher, the sea floor represents a proportionally greater resource. Frequently, wartime activity was directed at stopping sea commerce, resulting in significant UXO contamination in economically important areas, such as harbors and channels. Much of the U.S. underwater contamination has occurred near military practice and test ranges, which tend to be remotely located with minimal direct economic impact. Thus, clean up efforts at FUDS sites have typically ended at the water's edge. However, sites that were remote 50 years ago are often no longer so, and potential hazards to the public from encounters with underwater ordnance are beginning to arise.

CORE STATEMENT OF NEED FOR FY 2005
UNEXPLODED ORDNANCE – UXSON-05-02

DUAL MODE NAVIGATION FOR PORTABLE PLATFORMS

OBJECTIVE: The goal of this SON is to develop dual-mode navigation tools to support the collection of geophysical data using hand-held or man-portable sensors. The navigation system should be capable of operating in rough, vegetated terrain, where handheld sensors will be required and where satellite access (Differential Global Positioning System [DGPS] coverage) is often limited. The first (coarse) mode would be used for logging of anomalies in search mode and would permit efficient reacquisition. The minimum performance requirement is approximately +/- 0.3 m rms absolute error, and the desired objective +/- 0.1 m, for X,Y coordinates (i.e., in the horizontal plane). No Z or vertical navigational information is required for the coarse mode. A second (fine) mode would support the collection of high-density data in the vicinity of the anomaly that would support the requirements of discrimination algorithms. This mode would require highly accurate, relative positioning to create local maps of single anomalies. The minimum performance requirement for the fine mode is +/- 0.10 m rms relative error, and the desired objective +/- 0.01 m in the X,Y, and Z coordinates. The two modes will not necessarily use the same base technology, but should be selectable with easy operator switching between modes. A system suitable in size, weight and power requirements for a hand-held or cart-mounted platform and compatible with geophysical sensors is required.

Proposers should demonstrate how their efforts will interact with or exploit other on-going research, development, or demonstration activities addressing UXO site characterization and/or remediation efforts. Proposals should address expected system costs, set-up time, range, sampling rates, environmental factors affecting performance, potential integration with geophysical instruments, and any other factors that would affect the suitability of the technology for UXO mapping. Work conducted in response to this statement of need is expected to culminate in a prototype system ready to be validated through subsequent field demonstrations.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for BRAC, at FUDS and other closed ranges. The detection and remediation of UXO at closed, transferred and transferring (CTT) ranges, munitions burning and open detonation areas, and burial pits is the one of the DoD's most pressing environmental problems. The UXO characterization and remediation activities conducted at DoD sites using currently available technology often yield unsatisfactory results and are extremely expensive, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and non-hazardous items. Field experience indicates that often in excess of 90% of objects excavated in the course of a UXO remediation are found to be non-hazardous items (false alarms). As a result, most of the costs to remediate a UXO site are currently spent on excavating targets that pose no threat.

The UXO remediation technology program seeks to both maximize the probability of detection and minimize the false alarm rate. Recent advances in sensors and signal processing have shown improvements are achievable in both metrics. However, the application of these techniques requires precise knowledge of the position of sensor data points. Careful application of current navigation technology can support the implementation of these advanced systems in open areas, although further improvements in open area navigation are still needed. Since currently available navigation technology suitable for obstructed sites is limited in both accuracy and range, application of these systems to challenging terrain and wooded areas will require new navigation techniques.

CORE STATEMENT OF NEED FOR FY 2005
UNEXPLODED ORDNANCE – UXSON-05-03

INNOVATIVE MAGNETOMETER OR ELECTROMAGNETIC INDUCTION SENSORS AND PROCESSING

OBJECTIVE: The goal of this SON is to develop novel sensors and signal processing techniques applicable to the diverse detection and discrimination problems of UXO-contaminated sites. Capabilities are needed for a wide variety of site conditions, particularly those with difficult geology, terrain and vegetation, and complex ordnance and clutter distributions. Many sites or sections of sites have sparsely distributed surface and subsurface ordnance and clutter items that can clearly be separated, while other areas have almost continuously overlapping suspected items, which need to be assessed. On some sites, access is severely limited by dense surface vegetation or terrain and 100% mapping from a ground platform is impractical. Ordnance ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in the subsurface. Proposals addressing either of the two following objectives will be considered under this SON.

Sensor Development. The first goal of this SON is to develop next generation electromagnetic geophysical sensors to collect vector data, either in the active or passive mode. Sensors that can increase stand-off distance or allow comprehensive search with less than 100% terrain coverage are particularly of interest. Sensors suitable for hand-held, man-portable, vehicular and airborne platforms are of interest. Sensors currently used for digital geophysical mapping are dominated by Cs-vapor magnetometers and coil-based electromagnetic sensors. These sensors provide high sensitivity, but point measurements provide limited information about the magnetic or electromagnetic signatures of buried items. As a result, high density spatial maps of anomalies are required for target localization and determination of target parameters. The objective is to develop a sensor that will provide vector or tensor measurements with more complete characterization of the local magnetic or electromagnetic response, such as would be available from multiple-axis vector or gradiometric measurements, in either an active or passive mode.

Signal Processing Applicable to Complex Data Sets. The second objective of the SON is to advance the processing techniques available to treat complex multi-axis data streams. Examples of data sets of interest include multi-axis, vector, or tensor magnetic and/or electromagnetic induction data. Proposals applicable to the extraction of multiple discrete targets from complex backgrounds and that exploit the unique aspects of these rich multi-axis data sets are particularly of interest. Proposed projects should result in processing advances that can be applied to data collected by current or next generation geophysical sensors. Approaches may be implemented in real time or require post processing. Data sets acquired using sensors on hand-held, man-portable, vehicular and airborne platforms are all of interest.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for BRAC, at FUDS and other closed ranges. The detection and remediation of UXO at CTT ranges, munitions burning and open detonation areas, and burial pits is the one of the DoD’s most pressing environmental problems. The UXO characterization and remediation activities conducted at DoD sites using currently available technology often yield unsatisfactory results and are extremely expensive, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and non-hazardous items. Field experience indicates that often in excess of 90% of objects excavated in the course of a UXO remediation are found to be non-hazardous items (false alarms). As a result, most of the costs to remediate a UXO site are spent on excavating targets that pose no threat. The UXO remediation technology program seeks to both maximize the probability of detection and minimize the false alarm rate. The goal is to meet the highest probability of detection desired (near 100%) at each site while reducing the false alarm rate by a factor of up to 100 for highly cluttered sites.

CORE STATEMENT OF NEED FOR FY 2005
UNEXPLODED ORDNANCE – UXSON-05-04

SYSTEMS INTEGRATION STUDY

OBJECTIVE: The goal of this SON is to support system-level studies to specify characteristics of potential future optimal UXO detection/discrimination systems. Proposals under this SON may address hand-held, man-portable, vehicular or airborne platforms. Recent and on-going projects under SERDP and other funding have explored multiple aspects of sensor and platform development, signal processing, and phenomenology. Integrating these multiple aspects to produce an ideal detection and discrimination system will require trade-offs of many inter-related variables that will constrain performance at the systems level. These include but may not be limited to platform stability, power consumption, navigation, data rates, processing strategies, sensor receivers and transmitters and many others.

Capabilities are needed for a wide variety of site conditions, including those with difficult geology, terrain and vegetation, and complex ordnance and clutter distributions. Many sites or sections of sites have sparsely distributed subsurface ordnance and clutter items that can clearly be separated, while other areas have almost continuously overlapping suspected items, which need to be assessed. Ordnance ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in the subsurface.

The research and development proposed under this SON should provide innovative advanced concepts that support achievement of one or more of the UXO technology objectives for wide area surveillance, production ground surveys or cued identification. The objective of this SON is to develop multiple system concepts with clearly identified sub-system performance requirements that if developed are projected to lead to significant improvements in detection and discrimination performance for hand held, man portable, vehicle towed or airborne systems. Identified sub-system performances such as power, platform stability, navigation, and sensor components do not need to be existing technology but should be capable of being developed in the near term (<4 years). This solicitation will not accept proposals for hardware development or the development of processing software.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for BRAC, at FUDS, and at other closed ranges. The detection and remediation of UXO at CTT ranges, munitions burning and open detonation areas, and burial pits is the one of the DoD’s most pressing environmental problems. The UXO characterization and remediation activities conducted at DoD sites using currently available technology often yield unsatisfactory results and are extremely expensive, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and non-hazardous items. Field experience indicates that often in excess of 90% of objects excavated in the course of a UXO remediation are found to be non-hazardous items (false alarms). As a result, most of the costs to remediate a UXO site are currently spent on excavating targets that pose no threat.

The UXO remediation technology program seeks to both maximize the probability of detection and minimize the false alarm rate. The goal is to meet the highest probability of detection desired (near 100%) at each site while reducing the false alarm rate by a factor of up to 100 for highly cluttered sites. These two metrics are closely coupled and must be tackled jointly. In all our technology objectives, the DoD UXO Research, Development Test & Evaluation (RDT&E) program is striving to provide tools and full visibility to site managers, regulators and communities concerning the expected performance and associated cost and impact for any cleanup decision.

SEED STATEMENT OF NEED FOR FY 2005
UNEXPLODED ORDNANCE – UXSEED-05-01

INNOVATIVE APPROACHES TO UNEXPLODED ORDNANCE (UXO) CLEANUP

OBJECTIVE: The overall goal of this SON is to develop proof of principle for new sensors, explore new discrimination techniques, develop new removal or disposal technologies, or to explore technologies that support such efforts through improvements in navigation, geo-location or ground, water, or aerial vehicle technologies. Advances are needed in all aspects of the detection, discrimination and disposal of UXO in both land and water environments. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in a variety of environments, using a variety of supporting vehicle and navigation technologies. Algorithms are needed that can exploit data from current state-of-the-art sensors and advanced sensors that are now becoming available. Once hazardous and non-hazardous items are distinguished, the hazardous items must be removed and/or disposed of in a cost-effective manner. The proposed work should, if successful, lead to a continued development effort, which ultimately could result in the fielding of new sensors, implementation of algorithms, testing of removal or disposal techniques, or in improving operation of the approaches used to date though improved navigation, geo-location or vehicle performance. There is interest in any aspect of improving UXO clean-up procedures in both land and water environments.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for BRAC and a FUDS in both land and water environments. Using current technologies, the cost of identifying and disposing of UXO in the U.S. is estimated to be in the billions of dollars. In the land environment, current technology has shown the ability to detect individual sub-surface UXO, but not to reliably discriminate UXO from other items that pose no risk. Thus, typical survey methods currently employed require an exhaustive search of contaminated areas, have an excessive level of false alarms, and lead to expensive removal and disposal procedures with potentially adverse environmental impacts. Presently, there exists no effective capability to survey underwater areas and map the location of all UXO for site characterization and remediation. Removal and disposal techniques for underwater UXO could be improved.

APPENDIX G
List of Acronyms

λ-MnO2	lambda-manganese dioxide
1,2,3,4-TeCDD/F	1,2,3,4-tetrachlorobenzene/1,2,3,4-tetrachlorodibenzofuran
2ADNT	2-amino-4,6-dinitrotoluene
1D	one-dimensional
2D	two-dimensional
3D	three-dimensional
3DSMF	Three-Dimensional Steerable Magnetic Field
4ADNT	4-amino-2,6-dinitrotoluene
ADNT	4-amino-2,6-dinitrotoluene
AEC	Army Environmental Center
AEM	active electromagnetic
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFP	Amplifying Fluorescent Polymer
AFRL	Air Force Research Laboratory
AFTOC	Air Force Total Ownership Cost
AIRSAR	Airborne Synthetic Aperture Radar
ALGLE	Aging Landing Gear Life Extension
AN	ammonium nitrate
AP	Ammonium Perchlorate
APG	Aberdeen Proving Ground
APIMS	Air Permit Information Management System
ARA	Applied Research Associates
ARDEC	U.S. Army's Research Development and Engineering Center
ARU	Autonomous Recording Unit
As	Arsenic
AVRIS	Advanced Visible Infrared Imaging Spectrometer
B-IBI	Benthic Index of Biotic Integrity
BAA	Broad Agency Announcement
BAM-PPV	poly(bis-(N-methyl-N-hexylamino)phenylene vinylene
BAMO-AMMO	3,3-bis(azidomethyl)oxetane-3-azidomethyl-3-methyloxetane
BCC	Birds of Conservation Concern 2002
BCVI	Black-Capped Vireo
BMP	best management practice
BRAC	Base Realignment and Closure
C	Carbon
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAH	Chlorinated Aliphatic Hydrocarbon
CARB	California Air Resources Board
CATS	controlled archaeological test site
CCA	Chromated Copper Arsenate
CCC	Chromate Conversion Coating
CCR	current channeling response

Cd	Cadmium
CD	chlorite dismutase
CERL	Construction Engineering Research Laboratory
CER	Consolidated Emissions Reporting
CFD	Computational Fluid Dynamics
CH3OH	methanol
CHTC	Catalytic Hydro-Thermal Conversion
$C1O_4^-$	perchlorate
CMB	Chemical Mass Balance
CO	Carbon Monoxide
CONUS	continental United States
CP	Conductive Polymer
Cr	Chromium
Cr^{+6}	hexavalent chromium
CRADA	Cooperative Research and Development Agreement
CSS	Coastal Systems Station
CTT	Closed, Transferred and Transferring
Cu	Copper
CWA	Clean Water Act
DANT	2,4-diamino-6-nitrotoluene
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DCE	Dichloroethene
DCL	Dillon Consulting Ltd
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DHANT	2,4-dihydroxylaminotoluene
DHS	Department of Health Services
DIRB	Dissemilatory Iron Reducing Bacteria
DLSME	Defense Land Systems & Miscellaneous Equipment
DNA	T-Deoxyribonucleic Acid
DNAPL	Dense Non-Aqueous Phase Liquid
DNB	dinitrobenzene
DNT	dinitrotoluene
DNTS	Dover National Test Site
DOC	dissolved organic carbon
DoD	Department of Defense
DOE	Department of Energy
DPA	Diphenylamine
DPRB	dissimilatory perchlorate-reducing bacteria
DSB	Defense Science Board
DSC	Defense Supply Center
DTAG	digital acoustic tag
DTIC	Defense Technical Information Center
DUSD(I&E)	Deputy Under Secretary of Defense (Installations and Environment)
DWT	Discrete Wavelet Transform
EA	Environmental Assessment
EAE	Environmentally Acceptable Endpoint
EAP	electroactive polymers
ECMI	Ecosystem Characterization and Monitoring Initiative

Eco-SSL	Ecological soil screening level
ECR	eddy current response
ECRS	Experiment Controlled Release System
EDYS	Ecological Dynamics Simulation
EI	Emissions Index
EIS	Electrochemical Impedance Spectroscopy
ELPI	Electrical Low Pressure Impactor
EM	electromagnetic
EM	energetic material
EMI	electromagnetic induction
EMIS	EM induction spectroscopy
ENTA	1,1-(N,N'-ethylenedinitramino)-3,3,5,5-tetraazidocyclotripphosphazene
EO	Executive Order
EOD	Explosive Ordinance Disposal
EPA	Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-To-Know
EQT	Environmental Quality Technology
ERC	explosive-related compound
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESD	Electro-Spark Deposition
ESTCP	Environmental Security Technology Certification Program
EWG	Executive Working Group
eXchange-DENIX	Defense Environmental Network and Information
FC	Fort Carson
FD	frequency-domain
FDEM	frequency domain
FEM	Finite Element Modeling
Fe^{o}	zero valent iron
FERM	Fire Ecology Range Management
FeS	iron sulfide
FLBGR	Former Lowry Bombing and Gunnery Range
FOPEN	Foliage Penetration System
FPGA	field programmable gate array
FRR	Fast Repetition Rate
FTIR	Fourier Transform Infrared Reflectance
FUDS	Formerly Used Defense Sites
GA	genetic algorithm
GCWA	Golden-Cheeked Warbler
GIS	Geographic Information System
GMS	Groundwater Modeling System
GPR	Ground-Penetrating Radar
GRFL	Groundwater Remediation Field Laboratory
GUI	Graphical User Interface
HAP	Hazardous Air Pollutants
HCB	hexachlorobenzene
HCCO	formaldehyde
HCI	Hydrogen Chloride
HFBA	Hierarchical Foreground Background Analysis

HFS	High Frequency Sounder
HMM	hidden Markov model
HMNAz	3-hydroxymethyl-3-nitroazetidine
HMT	hidden Markov tree
HMX	octahydro-1,3,5,7-tetranitro 1,3,5,7-tetrazocine
HNF	hydrazinium nitroformate
HNIW	Hexanitrohexaazaisowurtzitane
HOC	hydrophobic organic compound
HSI	Hyperspectral Imaging
HTS	high temperature superconducting
HVOF	High-Velocity Oxygen Fuel
ICA	independent components analysis
ID	internal diameter
IID	impact initiated device
IMU	inertial measurement unit
INRMP	Integrated Natural Resource Management Plan
IPR	In-Progress Reviews
ISCO	In Situ Chemical Oxidation
ISIN	Integrating Sphere Integrating Nephelometer
ITAM	Integrated Training Area Management
ITL	Information Technology Laboratory
ITRC	Interstate Technology Regulatory Council
JEMP	Joint Engineers Management Panel
JG-PP	Joint Group on Pollution Prevention
JHU/APL	Johns Hopkins University/Applied Physics Laboratory
JPL	Jet Propulsion Laboratory
LAFB	Langley Air Force Base
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory
LFEP	Lead Free Electrical Primer
LIBS	Laser-Induced Breakdown Spectroscopy
LLNL	Lawrence Livermore National Lab
LM	Liquid Molding
LO	low observable
LOD	Low-Order Detonation
LS	Lignosulfonates
LW	Land Warrior
LWSC	Low Water Stream Crossing
MA	Mechanical Alloying
MagRAM	Magnetic radar absorbing material
MARAD	Maritime Administration
MARPOL	International Maritime Organizations Marine Pollution Convention
MBTA	Migratory Bird Treaty Act
MEK	Methyl Ethyl Ketone
MFA	magnetic field angle
Mg	Magnesium
MIC	Metastable Intermolecular Composites
mLEAN	Military Land Use Evolution and Impact Assessment Model

MLFMA	Multi-Level Fast-Multipole Algorithm
MMPP	Miscellaneous Metal Parts and Products
MMR	Massachusetts Military Reservation
MNA	monitored natural attenuation
MNX	mononitroso derivative
MRE	Meal Ready-to-Eat
MRT	Magnetic Remanence Technology
MSAT	Mobile Source Air Toxics
Msec	milli-second
MTADS	Multi-Sensor Towed Array Detector System
MTBE	Methyl Tert-Butyl Ether
MTG	Magnetic Tensor Gradiometer
MTH	Magnesium, Teflon, and Hytemp
MTTP	magnesium, Teflon, and polystyrene or ethylene-vinyl acetate thermoplastic binder
MTV	Magnesium, Teflon, and Viton
MURI	Multiple University Research Initiative
MUX	multiplexer
MWM	meandering winding magnetometer
NA+	Sodium
NADAG	North American Database of Archaeological Geophysics
NADEP	Naval Aviation Depot
NAGPRA	Native American Graves Protection and Repatriation Act
NAPL	Non-Aqueous Phase Liquid
NASA	National Aeronautics and Space Administration
NAVEODTECHDIV	The Naval Explosive Ordnance Technology Division
NAWCAD	Naval Air Warfare Center Aircraft Division
NAWCWD	Naval Air Warfare Center Weapons Division
NBVC	Naval Base Ventura County
NC	Nitrocellulose
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defense Center for Environmental Excellence
NDE	nondestructive evaluation
NDMA	1,4-dioxane, N-nitrosodimethylamine
NEETC	National Environmental Education and Training Center
NEPA	National Environment Protection Act
NESHAP	National Emission Standards for Hazardous Air Pollutant
NETTS	National Environmental Technology Test Site
NG	nitroglycerine
NGP	Next Generation Fire Suppression Technology Program
NH_3	ammonia
NH4+	ammonia
NIS	non-native invasive species
NIST	National Institute of Standards and Technology
NMR	Nuclear Magnetic Resonance
NMSim	Noise Model Simulation
NOAA	National Oceanic and Atmospheric Administration
NOD	Natural Oxidant Demand
NOx	Nitrogen Oxide
NPS	Naval Postgraduate School
NPS	Non-Point Source
NRHP	National Register of Historic Places

NSWC	Naval Surface Warfare Center
NSWCCD	Naval Surface Warfare Center Carderock Division
NTC	National Training Center
NTL	National Test Location
NU	Northeastern University
NV-LOC	No-VOC Low Observable Coating
O&M	Operation and Maintenance
OAP	Oligoaniline Acrylate Polymer
OB/OD	Open Burning/Open Detonation
OCONUS	outside CONUS
ODS	Ozone Depleting Substance
ODUSD(I&E)	Office of the Deputy Under Secretary of Defense (Installations and Environment)
ONR	Office of Naval Research
OPO	Optical Parametric Oscillator
ORD	Office of Research and Development
ORNL	Oak Ridge National Laboratory
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OSMIS	Operating and Support Management Information System
OX^-	Hypohalide iron
PAC	Project Advisory Council
PAH	Polycyclic Aromatic Hydrocarbon
Pb	Lead
PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzo-p-dioxins and dibenzofurans
PCE	Perchloroethylene
PEL	Permissible Exposure Limit
PELAN	Pulsed ELemental Analysis with Neutrons
PEN	potential excess nitrogen
PETN	pentaerythriol tetranitrate
PI	Principal Investigator
PIF	Partners in Flight
PM	Particulate Matter
PMS-EOD	Project Management System-Explosive Ordnance Disposal
PNNL	Pacific Northwest National Laboratory
pNITRED3	Nitroreductase Gene
POD	Point of Discharge
POI	Point of Impact
POLSAR	Polarimetric AIRSAR
polyNIMMO	Poly(3-nitratomethyl-3-methyl oxetane)
ppb	parts per billion
ppm	parts per million
PPP	Plastic Parts and Products
PRB	Permeable Reactive Barrier
PVC	polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
QSAR	Quantitative Structural Activation Reaction

R&D	Research and Development
RAM	Radar Absorbing Material
RCRA	Resource Conservation and Recovery Act
RDT&E	Research, Development Test & Evaluation
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
REMM	Riparian Ecosystem Management Model
REMPI	Resonantly Enhanced Multiphoton Ionization
RF	Radio Frequency
ROV	Remotely Operated Vehicle
RPI	Rensselaer Polytechnic Institute
RPM	Remedial Program Manager
RSim	Regional Simulation Model
RT3D	Reactive Transport Three-Dimensional
RUSLE	Revised Universal Soil Loss Equation
RX	receiver
S&O	smokes and obscurants
S&T	Science and Technology
SAB	Scientific Advisory Board
SAIC	Science Applications International Corporation
SAR	Synthetic Aperture Radar
SCAPS	Site Characterization and Analysis Pentrometer System
SCM	Source Characterization Model
SCORE	Southern California Off-Shore Range
SCOS	Southern California Ozone Study
SDSS	Spatial Decision Support System
SEAM3D	Sequential Electron Acceptor Model Three-Dimensional
SEAR	Surfactant-Enhanced Aquifer Remediation
SEED	SERDP Exploratory Development
SEM	spatially explicit model
SEMP	SERDP Ecosystem Management Program
SERDP	Strategic Environmental Research and Development Program
SMF	steerable magnetic field
SNDE	spectral nondestructive evaluation
SNL	Sandia National Laboratory
SNR	signal-to-noise ratio
SO_2	sulfur dioxide
SOC	Surface Optics Corporation
SOM	soil organic matter
SON	Statement of Need
SPAWAR	Navy Space and Naval Warfare Systems Command
SPG	scanning probe in a conducting gas
SQUID	Superconducting Quantum Interference Device
SROC	Senior Readiness Oversight Council
SWAT	Shallow Water Acoustic Toolset
T	Transition
TAC	Technical Advisory Committee
TACOM	(U.S. Army) Tank-Automotive & Armaments Command
TCE	Trichloroethylene
TCP	1,2,3-trichloropropane
TD	time-domain

TEM	time-domain electromagnetic
TES	Threatened or Endangered Species
TLM	Test Location Manager
TMDL	Total Maximum Daily Load
TMGS	Tensor Magnetic Gradiometer System
TOPSAR	Topographic Synthetic Aperature Radar
TNB	1,3,5-trinitrobenzene
TNT	2,4,6-trinitrotoluene
TPE	thermoplastic elastomer
TRAKER	Testing Re-Entrained Aerosol Kinetic Emissions from Roads
TRI	Toxic Release Inventory
TSE	Twin Screw Extruder
TTAWG	Technology Thrust Area Working Group
TX	Transmitter
UAT	Urban Air Toxic
UNDS	Uniform National Discharge Standards
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U. S. Geological Survey
UWB	Ultra Wide Band
UXO	Unexploded Ordnance
VAFB	Vandenberg Air Force Base
VAMOSC	Navy and marines Visibility and Management of Operating and Support Costs
VE	vinyl ester
VETEM	Very Early Time Electromagnetic
VOC	Volatile Organic Compound
VSP	visual sample plan
WASI	Wide-Area Spectral Imaging
WHOI	Woods Hole Oceanographic Institution
WKU	University of Western Kentucky
YPG	Yuma Proving Ground
YSZ	yttrium stabilized zirconium
YTC	Yakima Training Center
ZN	Zinc

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